THE CODLING MOTH

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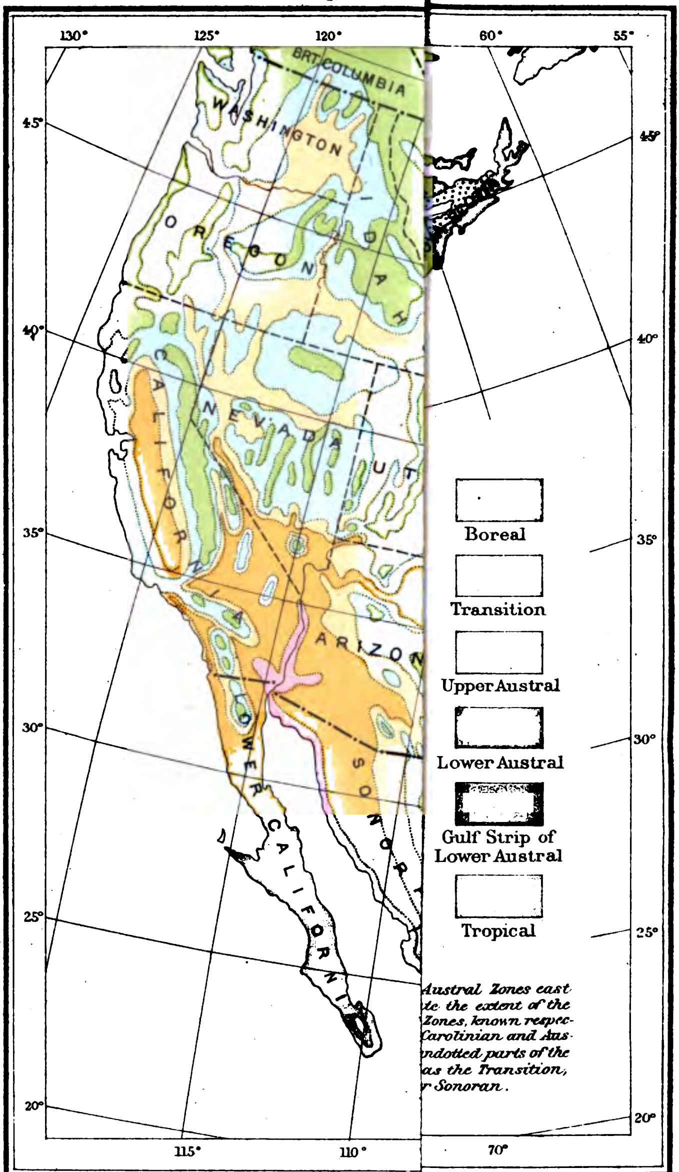

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U. S. DEPARTMENT OF AGRICULTURE.

DIVISION OF ENTOMOLOGY—BULLETIN NO. 41.

L. O. HOWARD, Entomologist.

THE CODLING MOTH.

PREPARED UNDER THE DIRECTION OF THE ENTOMOLOGIST

BY

C. B. SIMPSON,

SPECIAL FIELD AGENT.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Division of Entomology,
Washington, D. C., July 29, 1903.

Sir: I transmit herewith the manuscript of a report on the codling moth, prepared under my direction by Mr. C. B. Simpson, field agent of this Division. Mr. Simpson had been charged with a special investigation of the codling moth, more particularly in the Northwest, in answer to special requests for such study in the newly developing fruit interests of that region. The codling moth is undoubtedly the most important insect pest of apple and pear, and is the occasion of greater loss than all the other insect enemies of these fruits combined, entailing an annual shrinkage of values exceeding $11,000,000. Mr. Simpson's investigations covered a period exceeding two years, and have already been voiced in a small preliminary bulletin and in a Farmers' Bulletin giving condensed advice relative to the control of this insect. The present publication is the final and complete report, elaborating all of the conclusions and results of this special investigation. It will be a very useful document for all workers in applied entomology and of decided practical value for the fruit grower. The illustrations which accompany it are essential to the correct understanding of the experiments reported and of the text. I recommend that this report be published as Bulletin No. 41 of the Division of Entomology. As stated in the letter of transmittal of bulletin No. 40, the term "New Series" has been dropped.

Respectfully,

L. O. Howard,
Entomologist.

Hon. James Wilson,
Secretary of Agriculture.

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THE CODLING MOTH.

(*Carpocapsa pomonella* Linn.)

INTRODUCTION.

Every person is acquainted with "wormy apples," and many have seen the caterpillars in the fruit, while few know the history of the worm-like creature which causes the injury, or whence it comes or whither it goes.

If apple insects were classified in the order of the degree and extent to which they cause monetary loss, the codling moth would rank first, since it causes more injury than all other insect enemies of this fruit combined. It is the most serious drawback with which the apple grower has to contend, as from one-fourth to one-half of the apple crop of the United States is injured every year. The control of this pest, however, is not difficult when compared with that of many other insects, and hosts of apple growers are each year saving practically all of their crop from its ravages.

In the literature of the subject, one finds that Cato makes the first mention of this insect, and since that time almost every entomologist has studied it and written about it. By the writings of LeBaron, Walsh, Riley, Cook, Goff, Forbes, Howard, Slingerland, and many others, information about its life history and remedial measures has been disseminated, which have facilitated its control in the eastern part of the United States.

It was found that in the western United States the conditions were different from those in the East and that the recommendations which brought success in the East did not give satisfactory results in the West, and the necessity arose of making a close study of the western conditions. Among those who have written on the insect in the West are Messrs. Washburn, Koebele, Card, Aldrich, Gillette, Cordley, and Cooley.

The two principal accounts of this insect are those by Dr. L. O. Howard in 1888 and Prof. M. V. Slingerland in 1898. Both of these writings give a summary of what was known of the insect at those dates, with many original observations and suggestions for its control.

Slingerland's bulletin is especially comprehensive, partly because of the late date of its publication, and partly because a complete bibliography and valuable historical notes are given. The excellent observations and photographs are important features of this publication, which has been of the greatest assistance to the writer of this bulletin.

The writer is under obligation to many for the aid given in this work. Hon. Edgar Wilson, Hon. Fremont Wood, and Mr. W. F. Cash rendered assistance in carrying out the practical tests; Mr. Alex. McPherson, the State horticultural inspector, made observations and gave aid in many ways; Mr. S. M. Blandford, of the United States Weather Bureau, at Boise, kindly furnished the temperature data used; Mr. H. E. Burke, of the Department of Agriculture, assisted in the work in 1902, and did much valuable and accurate work upon the life history of the insect; Prof. C. P. Gillette and Mr. D. W. Coquillett kindly gave the writer access to their notes. Many fruit growers in Idaho have rendered especially valuable aid in keeping records. Professor Slingerland granted permission to use many of his figures, and his bibliography, with his notes, is used as a foundation for that portion of this bulletin. Prof. J. M. Aldrich, Prof. A. B. Cordley, and Prof. C. V. Piper have at all times given aid, counsel, and advice, and granted permission to use their unpublished data.

The estimates of injuries inflicted by the codling moth given in this bulletin are based principally upon observations made upon check trees in spraying experiments.

SYSTEMATIC POSITION.

The codling moth belongs to the order Lepidoptera, or scale-bearing insects, and has been assigned to the family Tortricidæ. The description of the genus *Carpocapsa* Treitschke, as given by Meyrick, is as follows:

> Antennæ in ♂ simple. Palpi moderate, curved, ascending. Thorax smooth. Forewings with termen slightly sinuate. Hindwings in ♂ with longitudinal groove below cell, including a hair pencil; 3 and 4 connate or stalked, 5 nearly parallel to 4, 6 and 7 closely approximated toward base. A small but rather widely distributed genus. * * *

The species *pomonella* is distinguished from the other species by having the margin of the ocellus (or black spot on the wing) of a coppery metallic color. (See Pl. VII.) The description of *pomonella* is given by Meyrick as follows:

> 14–19 mm. Forewings dark fuscous, finely irrorated with whitish, with darker striæ; basal patch sometimes darker; a large dark coppery brown terminal patch hardly reaching costa, anterior edge more blackish, ocellos within this edged with bright coppery metallic. Hindwings fuscous, darker terminally.

NAMES OF THE INSECT.

POPULAR NAMES.

The name "codling moth" is the one most generally used by the American fruit growers. The first name given to this insect was "pear eater," on account of its feeding in pears. Later writers called it the "apple and pear worm or moth," "fruit worm," "fruit moth," and many others names. The name "apple worm" is often used, especially by the English.

Wilkes, an English author, first used the name in 1747, which name was taken from a kind of apple tree. Slingerland says that the word "codling" is doubtless a corruption of the old English word "querdlying," which means any immature or half-grown apple. Some horticulturists and entomologists and others use the names "coddling" or "codlin." As a result of extended research Slingerland discards these names and gives the name "codling" decided preference.

SCIENTIFIC NAMES.

In 1758 Linnæus gave this insect the specific name of *pomonella* and the discription is as follows: "Alis nebulosis postice macula rubra aurea." Schiffermülier, 1776, named it "pomonana." Fabricius, 1793, gave it the name "pomona." By reason of the eighteen years priority the name "pomonella" stands.

Linnæus gave this insect the generic name of *Tinea*. Later it was known as *Pyralis*, *Tortrix*, *Semasia*, and *Erminea*. Still later it was given the name *Carpocapsa*, which was in use for about three-quarters of a century. In 1897 Walsingham concluded that the name *Carpocapsa* must fall and be replaced by *Cydia*. This view was adopted by Fernald in Dyar's list of North American Lepidoptera; but Cockerell strongly doubted this conclusion. After a very exhaustive study of the subject Mr. Busck concludes that the old name *Carpocapsa* is the proper name and must be restored, and his conclusions are accepted in this publication.

VARIETIES OF CODLING MOTH.

Staudinger described a variety of the codling moth which was bred from either apple or walnut in which the coppery spots in the ocellus were more broken and gave it the name of *putaminana*.

It has evidently been thought for many years that there was a variety of the codling moth in the far west. Matthew Cooke said in 1883: "From investigation it is probable that there are more than one species of codling moth infesting the fruit of this State [California], but I am not prepared to report at the present writing."

In 1900 the writer found one buff-colored moth which, except for color, was like the common codling moth, on the trunk of a tree at

Boise, Idaho. During 1901 four well-preserved specimens and eight badly worn specimens were secured. In 1902 six of these buff-colored moths were bred among 182 normal moths. In material collected in Idaho in the fall of 1902, from which about 30 moths emerged the following spring, five were of this variety. Mr. A. F. Hitt, of Weiser, Idaho, and Mr. Alex. McPherson, tell the writer that they have noticed these buff-colored moths. Mr. Hitt, in 1896, bred seven of these among 50 normal moths.

The writer submitted the moths to Mr. August Busck, of the United States Department of Agriculture, for determination, and in the Proceedings of the Entomological Society of Washington he describes them as follows:

> These specimens were submitted to the writer for determination, and I have carefully examinedt hem structurally in comparison with the common form of *Cydia* [a] *pomonella* Linné. I do not think there can be any doubt about their being this species; the oral parts, the venation, the secondary male sexual character of the hind wing, and the external sexual organs of both sexes are identically as found in the common dark form of the codling moth. The general pattern of ornamentation is also the same, but the coloration is so strikingly different that the variety deserves a special name, the more so as no intermediate forms seem to occur. I propose that it be known as *Cydia* [1] *pomonella* Linné, var. *simpsonii*.
>
> Instead of the dark fuscous color of the common form, the variety is light buff, with slightly darker buff transverse striation. In the common form the forewings are finely irrorated with white, each scale being slightly white tipped; in *simpsonii* the scales are not white tipped. The terminal patch, which in the common form is dark coppery brown, nearly black, and with dark violaceous metallic streaks, is in *simpsonii* light fawn brown with pure golden metallic streaks. The extreme apical edge before the cilia is in the common form black, in the variety reddish brown, and the cilia in *simpsonii* are light golden ocherous instead of the dark fuscous of the common form. The head, palpi, body, legs, and the tuft of hairs on the hind wings of the male are correspondingly light-buff colored in the variety instead of dark fuscous, as in the common form.
>
> Besides Mr. Simpson's specimens, in which both sexes are equally represented, there is in the United States National Museum a single female, labeled "Cook, California, July 30, 1883."
>
> Type: No. 6803, United States National Museum.

The writer has never observed any gradations between this variety and the common form. It is most probable that this variety is distinctly western, as there are no records of its having been bred in the East. No attempt was made to secure the earlier stages of the insect, and, as far as observations were made, its life history is similar to that of the normal form of the codling moth, as the larvæ from which this variety was bred were taken with the larvæ of the normal form under bands on apple trees. One might theorize on what conditions in the West have given rise to this new variety, but to state with any degree

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[a] The generic name *Cydia* used by Mr. Busck before his investigations, which resulted in the restoration of the old name *Carpocapsa*.

of certainty exactly what has brought about this change is impossible from the data at hand.

GEOGRAPHICAL DISTRIBUTION.

The original home of the codling moth is not definitely known, but is supposed to be southeastern Europe, the home of the apple. It has followed the distribution of the apple closely until it is now present, with but few exceptions, in all countries where apples are grown. It has spread over Europe, and is present as far as the apple region extends in Siberia. It was noted in Australia about 1855, Tasmania about 1861, New Zealand in 1874, South Africa about 1885, and Zeller received it from Brazil in 1891.

Mr. C. L. Marlatt reports that he did not observe this insect in either Japan or China in his extended travels in those regions. Mr. George W. Compere also states that he has never observed it in China. Prof. A. B. Cordley states that this insect has reached China. Evidently some correspondent of his has reported it as present in that country. As apples are being continually shipped to both Japan and China, it is but a question of a few years when it will either be introduced or become injurious in the orchards of those countries.

Extended researches of many investigators have failed to give date or definite information as to the time and manner of introduction of the codling moth into America. For a long time injury to the apple by this insect was thought to be the work of the plum curculio; and it was not till 1819 that the codling moth was reared from wormy apples by Burrell. It was evidently quite well distributed in the eastern United States before its work was identified, as there are but few records of its spread. In 1840 it was a serious pest in New England and central New York. About 1860 it invaded Iowa. For many years it has been a serious pest in Canada. Mr. Alexander Craw stated in 1893 that the insect was first introduced into California by means of some fruit brought from the East to Sacramento for exhibition purposes in 1872. No measures were taken to destroy the insects in this fruit, and two years later its presence in abundance was noted. Later it was rapidly distributed over the State, aided by the system of returning boxes. Dr. C. V. Riley mentions in 1876 that this insect was then present in Utah, where it had evidently been introduced a year or two previously.

From these points of infestation the codling moth spread over the Western States. Prof. J. M. Aldrich states that it has been known in the Clearwater Valley in Idaho since 1887. Mr. I. L. Tiner, of Boise, states that in 1887 he found the first indication of this insect at Boise, Idaho. Mr. Thomas Davis, of Boise, states that it was introduced into his orchard at about the same time.

RELATION OF DISTRIBUTION TO LIFE ZONES.

Although the codling moth may be brought into a section of country, it may not be able to obtain a foothold on account of the adverse climate. In other regions it is never very injurious, or it may be quite injurious one year and almost absent the next; but in warmer regions it reaches the maximum of destructiveness.

In order to study these conditions the writer has used the life zones of Dr. C. Hart Merriam (Pl. I). Upon consulting this map one finds that there are seven different zones in the United States. In the eastern portion they, in a general way, extend east and west, while in the western part they are broken into irregular areas by the mountain ranges. There are many important subdivisions of these zones, depending principally upon the amount of moisture and the milder and more temperate climate near the seacoasts.

BOREAL ZONE.

The principal apple-growing regions of this zone are in Nova Scotia, northern Maine, northern Michigan, and western Oregon. Except for the Pacific coast strip, only the more hardy varieties of apples are grown in this zone. There is a great lack of definite data in regard to the exact amount of injury the insect causes in this zone. As near as the writer can learn, the injury is never so great as it is in the next warmer zone. According to Cordley, the insect is present in small numbers in the Pacific coast strip and is doing but a comparatively small amount of injury.

TRANSITION ZONE.

The transition zone includes the greatest apple-producing regions of the United States, the Alleghenian area comprising the zone in the eastern mountain States, including the larger part of the apple-growing regions of New York, Pennsylvania, and Michigan. Although the injury, which varies with the seasons, is greater in the transition than in the boreal zone and less than in the austral, no record of definite percentages has been found during the present study.

In the arid area of the transition zone the loss is less than in the Alleghenian area. Various estimates of from 5 to 25 per cent of damage have been given. At Moscow, Idaho, which partakes more of the Pacific coast strip characteristics than of those of the arid area, Professor Aldrich records the amount of injury as 21 per cent for 1899, 10 per cent for 1900, and 5 per cent for 1901. Professor Piper states that in 1898 the average damage about Pullman, Wash., was 10 per cent, and some orchards were injured 25 per cent; in 1902, about 5 per cent. Professor Gillette reports from 35 to 80 per cent at Fort Collins, Colo., varying with the degree of infestation in the locality.

Cooley reports an injury of 95 per cent in small home orchards in Helena, Mont. There are many regions in this faunal area in which the insect does about 25 per cent damage, and for some reason, probably climatic, the injury is reduced to almost nothing for several years, after which the numbers of the insect gradually increase. Professor Aldrich records that in 1899 an early snowfall and low temperature at Moscow, Idaho, killed a great many of the larvæ. There are many other localities in the Pacific Northwest where the codling moth either has not been introduced or has not thrived, and in which the injury is nominal.

In many regions where the transition zone is pierced by valleys of the upper Sonoran zone the orchards near the canyons suffer much greater injury than those more remote therefrom. Professor Piper has noted several cases in which this was true, and in one the damage was 75 per cent or over.

THE PACIFIC COAST TRANSITIONAL AREA.

This area includes those portions of Oregon and Washington between the Coast Mountains and the Cascade Range, parts of northern California, and most of the coast region of the State from near Cape Mendocino southward to the Santa Barbara Mountains. In Oregon varying percentages of injury have been reported, ranging from a nominal loss to 75 per cent. In the Hood River Valley in some cases it is greater than this, with an average, perhaps, of about 25 to 90 per cent.

UPPER AUSTRAL ZONE.

The upper austral zone is divided into two areas by reason of the greater humidity of the eastern portion.

THE CAROLINIAN FAUNAL AREA.

This area includes the great apple regions of the Central States and many smaller portions of the Eastern States. Many entomologists have reported injury in these areas as ranging from 30 or 50 per cent to practically 100 per cent.

UPPER SONORAN FAUNAL AREA.

This area includes that portion of the upper austral zone west of the one hundredth meridian. From many countings and estimates from various sources we find that in badly infested districts the injury varies from 80 to 95 per cent under normal conditions, and it is very common to find the loss reach 100 per cent.

LOWER AUSTRAL ZONE.

In this zone there are only a few localities where apples are grown on a commercial scale. Under normal conditions in badly infested

localities the loss is almost total. Garcia records, from check trees in spraying experiments, that the loss varied from 67 to 99 per cent. There are many localities in this zone in both east and west where apples can be grown, but on account of the injuries due to the codling moth other crops are grown instead.

IMMUNE REGIONS.

In many regions of the Far West one often hears the fruit growers say that on account of the peculiar climatic conditions of that region apples are free from injury and the codling moth can not exist. Among these climatic conditions quoted are dense fogs, mountain breezes, and comparatively high altitudes. Seven or eight years ago it was thought that the Hood River Valley was immune from the insect; the same was thought of the Pajora Valley in California; but later developments have shown that immunity was due to the fact that the insect had not been introduced into those localities. It has also been said that there was no codling moth near the coast in Oregon, but Professor Cordley finds that it is present in some localities and believes that the former immunity was due to isolation.

In many restricted areas in the Pacific Northwest more or less isolated the codling moth is either absent or present in such small numbers that it has not been observed. From past experience and examination of these localities it is evident that the insect in its general spread has not yet reached them. It is a question whether or not the insect will be injurious in these localities, but it is certain that it can be present. The writer has no hesitancy in concluding that there is no region in the Pacific Northwest in which apples are grown in which the codling moth can not exist.

Many causes of immunity by isolation in river valleys have been noted. The most marked case is at Mr. I. B. Perrine's orchard at Blue Lake, Idaho. The nearest orchard is 18 miles distant down Snake River, while there are no orchards in the other direction inside of 75 to 80 miles. This orchard was free from codling moth until three or four years ago, the larvæ having undoubtedly been introduced in old apple boxes about that time.

MEANS OF SPREAD.

There are several ways in which the codling moth can be distributed. The most prolific source of distribution comes from the shipping of fruit from an infested region. Fruit which contains the larval insects may be shipped great distances, and when the larvæ complete their growth they spin cocoons, and in due time the moths emerge, and with unerring instinct seek the nearest apple trees. Many larvæ are found to have spun their cocoons in the angles and cracks of the boxes

FIG. 1.—APPLE LEAF INHABITED BY CODLING MOTH.

a, Point where larva entered midrib, at junction with one of the principal veins; *b*, portion of burrow exposed (photograph by Prof. A. B. Cordley).

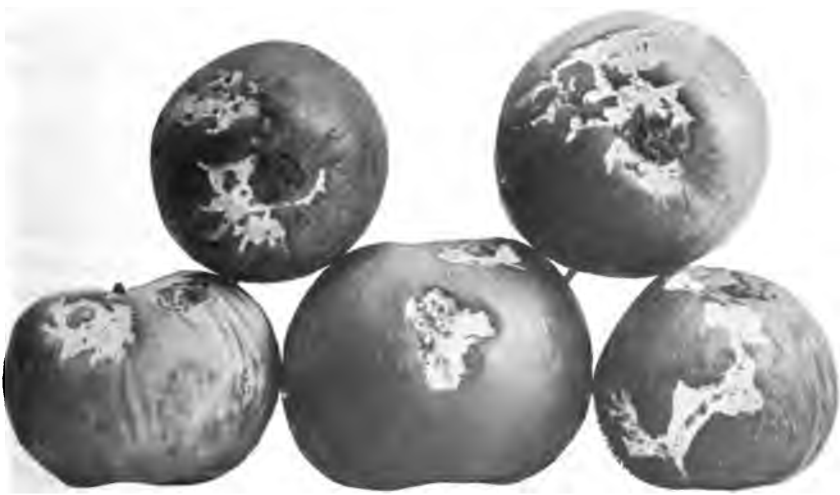
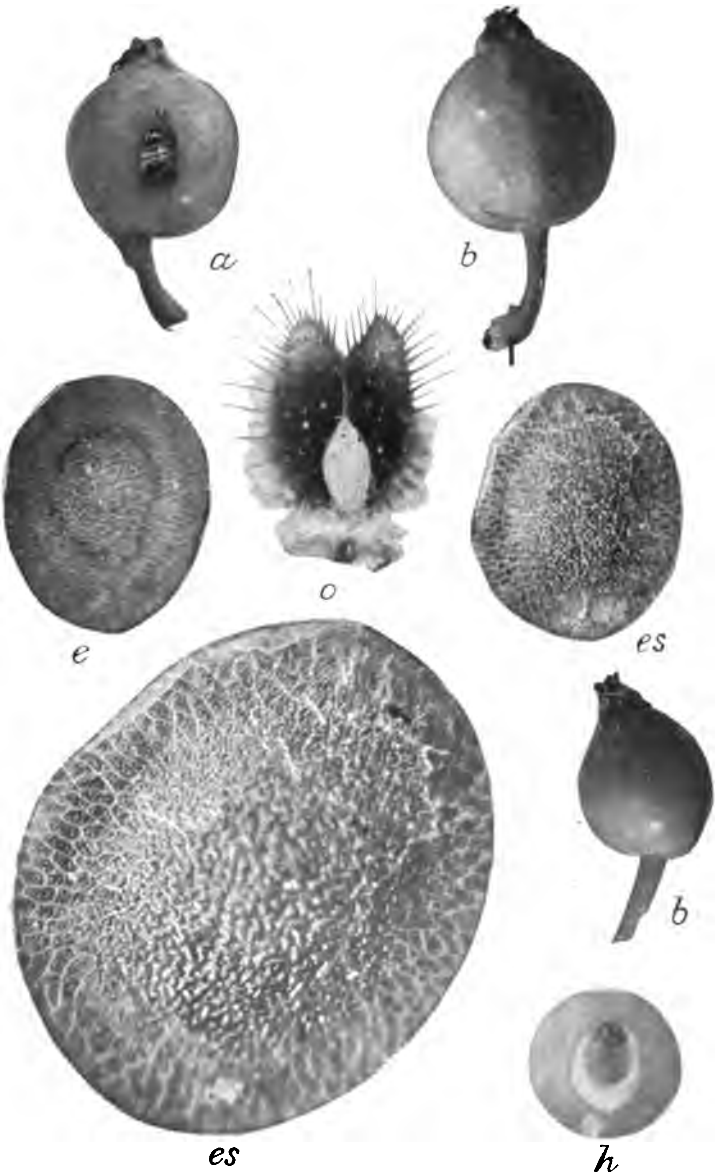


FIG. 2—APPLES DAMAGED BY UNKNOWN CATERPILLAR.

(Reduced from photograph by the author.)



EGGS OF THE CODLING MOTH.

Natural size of eggs at *a* and *b*; *e*, showing red ring in egg; *es*, egg, showing the hole through which the larva emerged; *h*, showing the egg enlarged, with the larva inside; *o*, the end of the ovipositor of the female. (From Slingerland.)

or barrels. In many localities it has been the practice to return to the fruit grower for refilling boxes in which fruit has been marketed. This practice has supplied the means of rapid distribution in such ocalities.

If infested fruit is shipped any distance in cars the larvæ spin their cocoons in cracks and holes in the walls of the car and may be carried great distances before the moths emerge. This is thought to have been the source of the infestation at Kalispell, Mont.

When apples are stored by commission houses the larvæ may crawl into boxes or cases of various kinds of merchandise and thus be widely distributed.

In sections where the orchards are near each other the spread is accomplished by the moth flying from one to another; but when they are many miles apart, which is especially the case in the Far West, this means of distribution doubtless has little influence. The insect can probably fly a few miles with the aid of the wind, but ordinarily 4 to 6 miles from a source of infestation, over unimproved land, gives partial if not complete immunity.

We have no authentic record of the distribution of the codling moth with nursery stock, but one can readily see how this could occur, as the larvæ might be in the cracks in the ground around the trees or night crawl into the packing and thus be carried great distances.

ESTIMATED LOSSES.[a]

Of all the insects affecting the apple the codling moth causes the greatest loss, and many estimates have been made of the damage. In 1889 Professor Forbes indicated an annual loss in the State of Illinois of $2,375,000. It is estimated that in 1892 the insect caused $2,000,000 loss in Nebraska. Professor Slingerland estimated that in 1897 the insect taxed the apple growers of New York $2,500,000 and the pear growers $500,000. In 1900 one-half of the crop of Idaho was damaged, while in 1901 the loss was much greater. Mr. McPherson estimated the loss in Idaho in 1902 as $250,000. In many sections of the Pacific Northwest the annual loss is from 50 to 75 per cent.

From the nature of the case it is most difficult to estimate the annual loss in the United States on account of the many factors which enter into the problem. By taking the estimates of the annual crops of apples as given by the American Agriculturist, it is found that for the years 1898, 1899, 1900, 1901, and 1902 the average crop was 47,000,000 barrels. From 1896 to 1902, inclusive, the average price at New York, Boston, and Chicago on October 20 of each year did not exceed $2. Allowing $1 for packing, transportation, and other charges, for

[a] The estimates under this heading have been revised from the original figures given by the author to correspond with the latest data.—C. L. M.

47,000,000 barrels at $1 we have a cash valuation of $47,000,000 for the first and second qualities.

It is well within the limits of safety to estimate that one-fourth more apples would have been placed on the market had it not been for the codling moth. This one-fourth would be about 12,000,000 barrels, and would have no value except for cider or local sale at very low price. The average price for cider apples is about 30 cents, which price would yield a total of about $3,600,000 as the value of the windfalls, culls, and cider apples, while if they were average apples, at $1 net per barrel the value would be $12,000,000, showing an annual loss of about $8,400,000. The loss in home orchards, in which the percentage of loss is far greater than in the commercial orchards, is estimated at $3,000,000, giving a total annual loss of $11,400,000.

The loss in the country at large or any section of the country will vary with the size of the apple crop. In years of full crops the comparative injury is not so great as in years when the crop is small and the prices high.

FOOD HABITS.

This insect is essentially a feeder upon rosaceous fruits, and to them all of the injury is done.

FRUITS INFESTED.

The apple is by far the most infested fruit. It is the natural food of the codling moth, and under ordinary circumstances is the only fruit injured, save pears. It is quite safe to assume that the larvæ of the codling moth originally fed upon the leaves of the apple and that the habit of burrowing in the fruit is acquired. Much has been said and written as to the resistance by different varieties of apple to this insect. In Bulletin 35, new series, Division of Entomology, the writer gave a list of varieties and indicated the resistance. It is a notable fact that the summer varieties of apples are very attractive to the second generation of insects. Varieties which are fragrant, as the Pewaukee and Ortley (Bellflower), are always badly infested. As a general rule, one can say that the harder and less ripe late apples are not attacked to the same extent as those which are ripe and fragrant when the second generation enters.

It is impossible, from the nature of the case, to determine the exact ratio of resistance of the varieties. In one orchard one will find fruit of the Ben Davis variety least infested, while in another it will be the most infested. These differences are without doubt due to local conditions in the different orchards.

Pears are next in order of infestation. Under ordinary conditions they are not injured to any great extent. In the Pacific Northwest in badly infested localities the injury rarely reaches a total of 20 per cent. When remedial measures are used this is reduced to from 5 to 15 per

cent. Several pear orchards have been noted which were located in neglected orchards in which there were few or no apples. The second generation of the insect seemed to concentrate its destructiveness on the pears, and in one case fully 80 per cent and in another about 50 per cent were injured. One fruit grower in Texas reports an injury of 50 per cent.

Crab apples are not usually so badly infested, but instances have been observed where they suffered fully as much.

Many records also show that peaches, prunes, plums, cherries, quinces, and apricots are infested by the codling moth, but under ordinary conditions their injury amounts to practically nothing. In cases where there is a lack of apples and the infestation is very abundant considerable damage results. There are records of 40 per cent injury to peaches where the trees were quite near an apple house in which infested fruit was stored.

NUT-FEEDING HABITS.

There are several European records of this insect in walnuts and oak galls. In 1887 Dr. Howard carefully sifted these reports, and concluded that the evidence was not sufficient to definitely prove that the insect ever feeds upon either walnuts or oak galls; and it was highly probable that the larvæ, if they were larvæ of the codling moth, went into the latter for the purpose of spinning their cocoons.

In 1895 Mr. Adkin exhibited a specimen of *C. pomonella* which was bred from a species of chestnut, and in 1896 gave details as to rearing this insect from walnuts, and offers the explanation that these nuts bear fleshy coats, or that the insect was originally a nut feeder. Theobald in 1896 wrote that in his investigations, extended over many years, he had never himself bred *Carpocapsa pomonella* from walnuts, but had found both *C. splendana* and *Plodia interpunctella*. Mr. West stated that he had also bred the insect from chestnut.

Dr. Riley in 1869 recorded that he had a specimen of a moth which had been bred from the sweetish pulp of a species of screw bean (*Strombocarpa monoica*) obtained from the Rocky Mountains. Professor Cockerell raises the question of the correctness of this record. In 1894 Professor Bruner reported that it is highly probable that the insect feeds in the seed buds of roses. In 1901 the writer carefully searched over many hundreds of these seed buds of roses near a badly infested orchard, and did not succeed in finding a single one that was in any way injured by the codling moth.

LEAF-FEEDING HABITS.

Professor Card in 1897 recorded that the young larvæ, especially in confinement, nibbled portions of the leaf. The writer has noticed many times leaves that had been eaten where he thought the work

was done by this insect. Professor Cordley has succeeded in making some observations upon this leaf-feeding habit which are of great value. In a recent letter to the writer he details his experiences as follows:

It was found on June 4 that these eggs had hatched and nearly all of the larvæ were dead. Two of them, however, had fed upon the leaves, were yet alive, and had made some growth, notwithstanding the fact that the leaves had been taken from the tree nearly a month before and were therefore presumably not in the most palatable co - dition. Both larvæ were feeding upon the lower parenchyma of the leaf, and one had completely covered itself with a web holding pellets of frass. A recently hatched larva, mounted in balsam, measured 1.35 mm. in length; the larger of these two larvæ at this time measured 1.80 mm. in length and was proportionately stouter. Both were transferred to fresh leaves, upon which they fed until June 8, when one of them disappeared. The other continued to feed until June 11, when it too disappeared. However, I noticed a slight discoloration of the midrib of the leaf, near where this larva had been feeding, and on carefully opening it found the larva feeding as a miner, it having already excavated a tunnel about 15 mm. long. I then examined the other leaf, in which I found the larva that had disappeared three days before likewise feeding in the interior of the midrib. The larvæ were again transferred to fresh leaves, and by the following morning each had again disappeared within a midrib. Both larvæ continued to feed within the midribs until June 16, when one of them, on being transferred to a fresh leaf, refused to eat and soon died. The other, with occasional changes to new pastures, continued to thrive until June 25, when it was plump and active and apparently in the best of health and spirits. Unfortunately I was then absent from the laboratories for some days, and when I returned the larva was dead. I believe that with careful attention it could have been brought to maturity on a diet of leaves alone. When one considers that it lived and grew for more than three weeks upon leaves that had been severed from the tree sometimes for several days, and that it was apparently more thrifty between June 16 and 25 than in the earlier days of its existence, one must acknowledge that, while the proof is by no means positive, the indications are that codling moth larvæ may fully develop on a diet of perfectly fresh apple leaves without ever having tasted fruit. (See Pl. II, fig. 1.)

The writer has many times taken larvæ from apples and placed them upon leaves in cages and bottles. It was found that the larvæ would fasten the leaves together with silk and eat holes in them; but on account of lack of attention no larvæ were bred to maturity. The writer believes, and agrees with Professor Cordley in believing, that the larvæ with proper care can be brought to maturity on the leaf diet alone.

This question of the leaf-feeding habit of the codling moth is one of the most important questions in the life history of the insect, and should especially commend itself to entomologists for future investigation, since not only will it give us a very important biological fact, but it will also prove very definitely how spraying is effective against the insect.

It has often been recorded that larvæ gnaw cavities in rough rotten wood, bark, cloth, paper, and other places where they spin cocoons, and the bits of these substances incorporated in the cocoons. From

observation it is evident that the larvæ do not eat any of these substances. When Paris green was placed under the bands and on the bark and in other places where the larvæ spin, it was found that none were killed, even when the poison was abundant, which tends to show that they do not eat of these substances.

PRIMITIVE FOOD HABITS.

Writers have indulged in speculation as to the primitive food habit of this insect. The other species of the genus are nut feeders, and Adkins expresses the opinion that this insect was originally such, and that the habit of eating apples was acquired.

The older writers have said that the insect was probably a leaf feeder. From the experience of Professor Cordley this view appears to be the more probable one.

WORK OF OTHER INSECTS.

There are many other insects which feed on apples whose work may be taken for that of the codling moth by those who are not familiar with the characteristics of the respective insects; but in all instances there are differences in the work and habits of the insects by which they may be easily distinguished.

The apple maggot (*Trypeta pomonella*).—This insect is quite injurious in the northeastern States, and its work in the apple is characterized by many winding tunnels through the fruit. The larva is footless, and has no distinct head, but tapers toward the front. This maggot is the early stage of one of the two-winged flies.

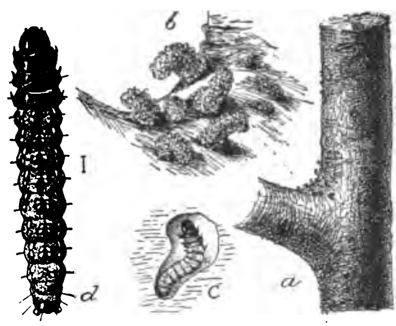


FIG. 1.—*Anarsia lineatella:* *a*, twig of peach, showing in crotch minute masses of chewed bark above larval chambers; *b*, latter much enlarged; *c*, a larval cell, with contained larva, much enlarged; *d*, dorsal view of young larva, more enlarged (from Marlatt).

The peach twig-borer (*Anarsia lineatella*).—Injury to peaches and plums by this insect is often attributed to the codling moth, as its second generation feeds in the fruit. The larvæ are much darker red and much smaller than those of the codling moth, and the mature larva tapers toward either end (fig. 1).

The plum curculio (*Conotrachelus nenuphar*).—This insect often attacks apples, but can be easily distinguished by the crescent-shaped scar made in egg laying, by the small punctures caused by the adult in feeding, and by the fact that the larva, though it has a distinct head, is footless.

The Indian-meal moth (*Plodia interpunctella*).—This insect feeds upon edibles of nearly all kinds—meal, grain, seeds, nuts, dried fruits,

etc. There is a common notion among some farmers that the larva of this insect is that of the codling moth, and the writer has often been told that the codling moth was introduced by its larvæ being imported in dried fruit. We have no reliable records of the codling moth having ever eaten dried fruit, and the Indian-meal moth is the principal insect that has been reared from such sources. The caterpillar is much smaller than that of the codling moth, and can be easily distinguished from it (fig. 2).

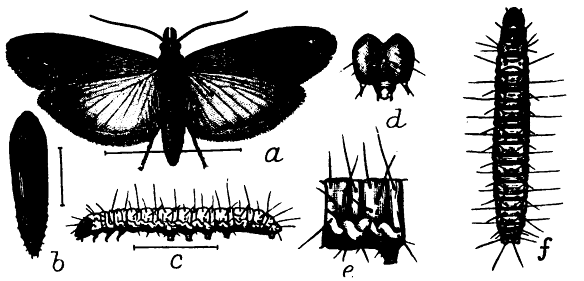


FIG. 2.—*Plodia interpunctella:* *a*, moth; *b*, chrysalis; *c*, caterpillar; *f*, same, dorsal view—somewhat enlarged; *d*, head, and *e*, first abdominal segment of caterpillar—more enlarged (from Chittenden).

The apple fruit-miner (*Argyresthia conjugella*).—The larva of this insect has been found attacking apples in British Columbia, and injuries which may have been caused by it have been noted in Washington, Idaho, and Montana. The larvæ are about one-fourth of an inch in length, are of a dirty white color, tinged with reddish when full grown, and taper at each end. The tunnels made in the fruit are numerous, and extend in all directions.

There are two species of Lepidoptera which do great damage to apples in Japan, which may sooner or later succeed in entering this country.

Apple fruit-borer (*Laverna herellera*).—This insect is said to have gained a foothold in British Columbia. The larvæ live only at the core of the fruit, injuring the seeds. When full grown they make a passage out, crawl or drop to the ground, and spin a white cocoon in the earth. They hibernate as pupæ, and there is only one generation each year. The species is shown in fig. 3, which also illustrates its manner of work.

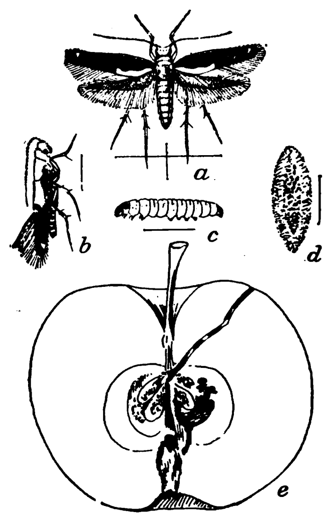


FIG. 3.—*Laverna herellera:* *a*, adult; *b*, same, side view; *c*, larva; *d*, cocoon; *e*, injured apple—all slightly enlarged except *e*, which is reduced (redrawn from Matsumura).

Pear fruit-borer (*Nephopteryx rubizonella.*)—It is stated that in Japan the pear crop is injured to the extent of 30 to 50 per cent each year by this insect. The eggs are laid in clusters on the twigs and

leaves, the larva making its way thence to the nearby fruits, which it enters. The principal work is around the core of the pear. The larval stage lasts three weeks or more, and the pupal stage is passed within the fruit. The insect hibernates in the egg stage. The moth, larva, and pupa are illustrated by fig. 4.

Unknown caterpillar working on outer surface of apples.—Opportunity is taken of presenting the reproduction of a photograph of apples injured by an insect, which in its larval stage somewhat resembles the codling moth, but which we have as yet failed to rear and identify.

The injury was first brought to the attention of the Division of Entomology by Mr. D. W. Coquillett in October, 1901. The apples furnished were purchased in open market in the city of Washington. The injury appeared to be almost exclusively on the outer surface, consisting in the cutting away of the skin and disfigurement of the apples and considerably depreciating their value as salable articles (see Pl. II, fig. 2). In some cases holes entering the fruit to the depth of about one-fourth of an inch were found; in one apple to the depth of one-half inch. In November Dr. L. O. Howard also furnished specimens of apples showing injury by the same species. One of the larvæ spun up and formed a cocoon November 6. Unfortunately all the larvæ died without our securing the moths. The following brief description of the larva was made:

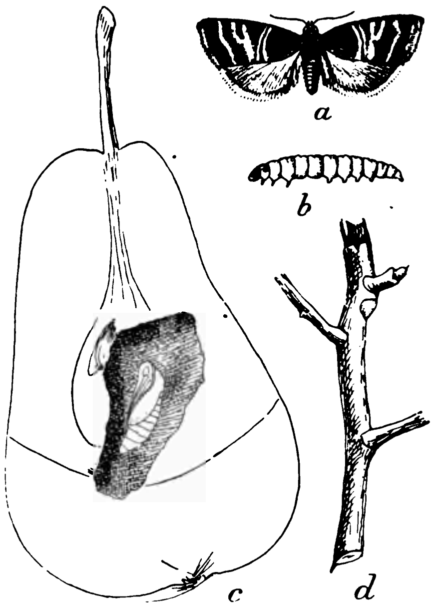


FIG. 4.—*Nephopteryx rubrizonella:* adult above, larva just beneath, egg mass on twig at right; damaged pear with pupa at left—all natural size (redrawn from Matsumura).

> Reddish flesh-colored, head dark brown, central portion of face whitish and transparent, with two black spots; cervical shield transparent, except for caudal margin Three setæ on the pre-spiracular tubercle. Length, five-eighths of an inch when spinning cocoon.

It will be noted that the injury illustrated and described is quite different from that mentioned and figured on pages 87 and 88 of Bulletin No. 10 (new series) of the Division of Entomology.

LIFE HISTORY.

Of all insects the codling moth has the largest number of biographers. It has been studied in nearly every country in the world and in all climates in which it exists. The early accounts were always more or less vague and inexact and gave rise to many false ideas. Gradually these points were worked out until to-day we can say that the life history of the insect is as well if not better known than that of any other. Yet, with all the knowledge we have of it, there remain several important points to be determined by future work.

It is a fundamental principle of economic entomology that in order to successfully combat an insect the life history of that insect must be given a keen, searching study. With few exceptions these studies reveal some point in the life of the insect at which it is vulnerable to preventive or remedial measures. Without this knowledge efforts are wasted and in some cases are a positive aid to the insects. It can not be too strongly urged that each fruit grower make himself familiar with the life history of the codling moth from personal observation, for by doing so he is placed in a position to understand the reasons for measures of control and to exercise his ingenuity in applying the same to his own orchard.

The ease with which collections can be made in the larval stage and the accessibility of literature pertaining to it should specially commend this insect to teachers as a subject for nature-study lessons.

In the present studies upon this insect particular care has been taken to keep the different stages under observation in exactly the same conditions of temperature, moisture, and light as were present in the orchard in which the cages were located, and as a result the writer is able to present some definite data in regard to the effect of temperature upon the length of the stages of the insect under normal conditions.

As in other lepidopterous insects, the life of the codling moth is divided into four distinct stages—egg, larva, pupa, and adult. In the winter and early spring the larvæ may be found in their cocoons in various places, as in cracks and holes in the trees. Later the larva transforms into a pupa, and this in turn changes to a moth, which in turn lays eggs.

THE EGG.

Since the time of Roesel many authors have mentioned the egg of the codling moth and stated where it was laid, but it was as late as 1893 that it was first accurately described and figured. In 1874 Mr. W. H. Hurlbut described the egg as being about one-eighth of an inch in length and nearly white. Riley described it as being very small and of a yellow color. Messrs. A. J. Cook, Koebele, Weir, and others undoubtedly saw the eggs, but Cook in 1881 and Miss M. Walton doubtless saw the eggs of some other insect.

In 1893 Professor Washburn gave an accurate description of the egg, with the first figure of it. This figure shows a well-formed embryo inside, but the network of ridges near the center is much too open.

Slingerland in 1896 and Card in 1897 distinguished the eggs and made many observations which added materially to our knowledge of this stage. In his 1898 bulletin Slingerland publishes many excellent photographs and descriptions which caused the eggs to be familiar objects. Influenced by Slingerland's and Card's work, Aldrich, Cordley, Gillette, and others have from time to time added to the sum of our knowledge of this stage of the insect. It is remarkable that, in spite of the many studies of its life history, the egg escaped notice for so long and when seen was not described and figured until a comparatively late date.

The egg is a flat, somewhat oval-shaped object with a flange around it. It varies in size from 0.96 to 1 by 1.17 to 1.32 mm. Commonly speaking, it is about the size of a pin head. The surface is covered with a network of ridges which are much closer together toward the central portion than around the edge. The color depends upon the age of the embryo; as when the egg is first laid it is of a pearly white color, sometimes with a decided yellowish tinge; later it is darker on account of the red ring. The eggs are always glued to the apple or leaf and one often finds shells which remain for some time after the larva has hatched. The reflection of light from the egg is of the greatest aid in finding them, and they have often been described as reflecting the light like "trout scales." (See Pl. III.)

PLACES WHERE LAID.

Having never seen the egg, the early writers were forced to guess as to where it was laid. They stated that the eggs were laid either in the stem end or in or about the calyx end of the apple. These views were held because of the position of the entrance holes of the larvæ. These ideas were published again and again for over a century, and American writers copied them until about 1897, when, by a series of observations, it was proved that they were incorrect. In 1889 Koebele and Weir stated that the eggs are laid at any point upon the apple and are "as a rule laid elsewhere than within the calyx." Washburn in 1892 found that the eggs were "placed on both sides and the top of the fruit." In the spring of 1896 Slingerland found that in confinement the moths laid eggs on the sides of the cages, on leaves, and on bark. Card in 1897 found that the eggs were laid almost exclusively upon the upper surface of the leaves, and in 1897 only 2 eggs were observed in the field. In a recent letter Professor Cordley states that out of 15 eggs laid in confinement the greater number were

on the fruit, and that he has never seen an egg of the first generation upon the fruit in the field.

The apparent contradictions of these observations may be accounted for by the fact that they were made upon the eggs of different generations of the insect. The writer has found that in Idaho but few of the eggs of the first generation are laid upon the fruit. In one limb cage a moth laid 21 eggs, only one of which was upon the fruit; and in another cage 24 eggs were laid and only 2 were upon the fruit. Very few eggs of this generation were observed to have been laid upon the fruit in the field. Professor Cordley suggests that the moth does not lay eggs upon the young fruit on account of the pubescence, which is afterwards lost. This is most probably the cause. In the field one can often find fruit, surrounded by leaves, upon which there are no eggs, while several may be found upon the upper surface of the leaves.

A good percentage of the eggs of the second generation are laid upon the fruit in the field. When the fruit is scarce a larger number is found upon the leaves. The average of several rough countings in the field gave an average of about 50 per cent laid upon the fruit. Breeding records show that out of 175 eggs of this generation in limb cages on inclosed branches and fruit there were 71 eggs upon the leaves, 95 upon the fruit, and 9 upon the twigs. Very few eggs are laid upon the underside of the leaves, and it seems that the moth much prefers a smooth surface upon which to oviposit.

We may therefore conclude that the eggs of the first generation are for the most part laid upon the leaves, while the majority of those of the second brood may be found upon the fruit.

WHEN THE EGGS ARE LAID.

Various writers have stated that the eggs were laid at night. Cooley records that he observed a moth depositing eggs at about sunset. The writer's observations show that the oviposition for the most part is accomplished in the late afternoon or early evening, while a single observation shows an egg to have been laid sometime between 9 and 12 o'clock in the morning.

THE NUMBER OF EGGS LAID BY ONE FEMALE.

There is probably less definite data on this point than on any other in the life history of the insect. Many guesses have been ventured as to the number of eggs that one female will lay, varying from 12 to 300 and over. LeBaron found from 40 to 60 eggs, with an average of 50, in various stages of development, in the ovaries of the female at the time of emergence. He adds that if all the undeveloped eggs came to maturity this number must be increased. Matthew Cooke said that he had a vial in his possession in which a codling moth laid 85

eggs. The writer was unable to secure eggs in this way. In only two instances has the writer made definite observations on the number of eggs laid by a single female moth. Two pairs of moths were secured in copula and placed in separate limb cages. In one cage 21 eggs were found, but as the moth escaped the observation was inconclusive. In the other cage 25 eggs were laid, but a spider put an end to the experiment before a definite conclusion was reached. In view of these incomplete observations the writer can only venture an opinion that the maximum number of eggs laid by one moth is about 50, with the average between 30 and 40, which is comparable to definite records of other insects of this family.

THE EGG-LAYING PERIOD.

Upon dissection of the ovaries of the female of the codling moth the eggs are found in various stages of development. It is also noted that eggs are laid when they are in different stages of maturity. From these facts we may conclude that the egg-laying period extends over some time. Various authors have given the length of time from the emergence of the moth to the beginning of the laying of the eggs as from 48 hours to 6 or 8 days. Professor Gillette gives the time as about 5 days. The various records of writers show that this time varies from 2 to 7 days, with an average of from 4 to 5 days.

DURATION OF EGG STAGE.

In 1746 Roesel stated that the egg hatched in 8 days. Recent authors give the length of the stage as follows: LeBaron, one week; Washburn, 5 to 10 days; Riley, 4 to 10 days; Slingerland, one week; Card, 8 to 10 days; and Professor Gillette, 6 to 8 days in his laboratory, with a known temperature, and in the orchard one day longer. Cooley records 12 days as the length of the stage of one egg.

The results of observations upon 164 eggs and observations of Professor Cordley are given in Table I, with the total and average effective temperature to which the eggs were subjected.

TABLE I.—*Duration of egg stage of codling moth.*

Date laid.	Number laid.	Date hatched.	Number hatched.	Period of incubation.	Total effective temperature.	Average effective temperature.
1902.		1902.		*Days.*	° *F.*	° *F.*
May 30	21	June 11	1	12	228	19
		June 12	3	13	253	19
		June 13	17	14	347	24.7
Aug. 11	1					
Aug. 12	7	Aug. 21	3	9	206	23
		Aug. 23	5	12	266	22
Aug. 16	6	Aug. 25	6	9	217	24
Aug. 26	9	Sept. 5	6	11	247	22
		Sept. 6	3	12	276	23

TABLE I.—*Duration of egg stage of codling moth*—Continued.

Date laid.	Number laid.	Date hatched.	Number hatched.	Period of incubation.	Total effective temperature.	Average effective temperature.
1902.		1902.		*Days.*	° *F.*	° *F.*
Aug. 27	27	Sept. 5	8	9	278	30
		Sept. 6	14	10	307	27
		Sept. 8	2	12	360	27
Aug. 28	61	Sept. 8	3	11	269	24
		Sept. 9	4	12	295	24
		Sept. 12	32	15	364	24
		Sept. 15	2	18	428	24
Do	14	Sept. 9	1	12	216	18
		Sept. 6	11	9	269	29
		Sept. 15	1	18	428	24
Aug. 29	40	Sept. 8	3	10	254	25
		Sept. 9	5	11	286	25
		Sept. 12	3	14	349	24
	187	....	164	243	....	....
CORDLEY.						
May 7	8	June 1	....	24	298	12
Do	15	May 12	....	5	285	47

The results under normal orchard temperature give the length of the stage from 9 to 18 days, with a weighted average of 11 days. This average is longer than has been given by other authors, which may be accounted for by the fact that it is the usual custom to keep the eggs in laboratories rather than under normal orchard conditions, and that the times of the laying of the eggs were estimated.

HATCHING OF THE EGG.

Recent authors are quite well agreed as to how the larva breaks or eats its way out of the shell. Professor Slingerland was most probably the first to observe this operation. He states that the larva came out of the egg near the edge at one end through an irregular crack in the shell. (Pl. III, *es.*) The writer has never observed this emergence, but upon examining many egg shells an irregular crack was always found which was almost always at one end of the shell.

CHANGES DURING INCUBATION.

When laid the egg is of a translucent pearly color, often with a yellowish tinge. Observations upon 88 eggs show that from 2 to 5 days with a weighted average of 3 days after being laid a red ring makes its appearance. This ring appears gradually at first whitish, then yellowish, and later quite a brilliant red. By observations upon 56 eggs it was found that in from 7 to 10 days, with a weighted average of 8.4 days after being laid, the egg loses the ring and in its place the larva can be seen, the "black spot," which consists of the head and cervical shield, being the most conspicuous part.

Professor Gillette states that his assistant, Mr. E. P. Taylor, found the red ring to appear in from 2 to 3 days after laying and the black

spot appeared 2 to 3 days later. This shorter average may be accounted for by the fact that these eggs were kept at a higher temperature than normal.

METHODS OF OBTAINING EGGS.

There are two ways of obtaining eggs for study. The first is to collect them in the field and place them under observation in cages. There is a serious objection to this method, as there is no way of knowing the age of the eggs. The second method, that of confining larvæ and pupæ and allowing the moths to emerge, is far more satisfactory. If these moths are placed in a cage over a limb of a tree, one will find eggs in abundance in a day or two. One is sometimes fortunate enough to find moths in copula, and in that event they should be placed in a separate cage. By determination of sex of the various moths much more valuable data can be secured. Care must be taken that too many eggs are not laid in one cage, as in that event it is difficult to keep accurate notes.

These limb cages are bags made of mosquito netting of finer mesh than the ordinary netting. By this method the leaves and fruit are always fresh and the conditions are exactly the same as in the orchard.

INFLUENCE OF TEMPERATURE UPON THE LENGTH OF THE EGG STAGE.

It has often been stated that a higher temperature caused the eggs to hatch in a shorter time, but only a few definite observations have been recorded. The temperature used in these calculations is the effective temperature, which is obtained by subtracting 43° from the mean daily temperature as recorded by the United States Weather Bureau station at Boise, Idaho.

Professor Gillette gives 6½ days as the length of this stage at a temperature of from 68° to 70° F. and 6 days as the time in a greenhouse where the temperature was 110° F. at midday. In Table I the total and average effective temperature is given from the time the eggs were laid until they were hatched. These data are arranged according to the temperature in Table II.

TABLE II.—*Effective temperature and period of incubation.*

Average effective temperature.	Total effective temperature.	Length of stage.	Average effective temperature.	Total effective temperature.	Length of stage.	Average effective temperature.	Total effective temperature.	Length of stage.
° *F.*	° *F.*	*Days.*	° *F.*	° *F.*	*Days.*	° *F.*	° *F.*	*Days.*
12	298	24	24	217	9	25	254	10
18	216	12	24	269	11	25	280	11
19	228	12	24	295	12	27	307	10
19	253	13	24	349	14	27	366	12
22	247	11	24	364	15	29	269	9
22	266	12	24	428	18	30	278	9
23	206	9	24	428	18	47	285	5
23	276	12	25	247	14			

Average total effective temperature, 302° *F.*

This table is not complete, in that not sufficient observations were made at lower and higher temperatures; and it is dangerous to make any extended conclusions therefrom. A study of the table shows:

First. Under a low temperature the length of this stage is longer than at high temperatures.

Second. The total temperature varies from 206° to 428° F., and the average is 302°; and in general eggs have to be subjected to this amount of heat before they hatch, whether it be for a longer or a shorter period of time.

Third. The eggs are not at the same state of maturity at the time of oviposition, as at 24° we have from 9 to 18 days as the length of stage.

Fourth. Under normal field conditions a small difference in temperature causes but little change in the length of the stage.

MORTALITY AMONG THE EGGS.

Various observers, among them Washburn, Goethe, Card, Slingerland, and Cordley, have found that many eggs of this insect did not hatch. There is little doubt that at least one of these writers mistook eggs from which the larvæ had hatched for dead eggs. The writer has noted that many eggs became hard and dry, while in others the contents changed to a dark brown color. These changes may have been caused by infertility, parasites, or the excessively hot sun. The mortality as shown by our breeding-cage records is by no means so great as the writer had supposed. The eggs, however, were more or less protected.

THE LARVAL STAGE.

Considering the codling moth in its economic relations, it may be said that the larval is the most important stage of the insect. Not only is it distributed, and does all of its damage in this stage, but it is more amenable to remedial measures.

At the time of hatching the young larva is from one-twentieth to one-sixteenth of an inch in length, of a semi-transparent whitish or yellowish color, with large, shiny, black head, and dark cervical and anal shields. The body shows regularly arranged spots with short hairs or setæ.

If hatched upon the apple the young larva seeks a place to enter, which is in general some irregularity upon the apple or at the calyx. Slingerland, Card, and Cordley have made many excellent observations upon the place of entrance. When hatched upon the leaves they may not find an apple for some time, and subsist by eating small portions of the leaves. In confinement this often occurs, but it has never been determined accurately how often it takes place in the field. The writer has time and again noted these spots on the leaves in the field, and has noted also that larvæ hatched on leaves would have to go from

10 to 20 feet before they could find an apple. Card notes that comparatively few eat of the leaves in the open, but from such observations as we have the writer is strongly of the opinion that it is quite a general habit.

DESCRIPTION OF FULL-GROWN LARVA.

When full grown the larvæ are about three-quarters of an inch in length, and their heads measure from 1.54 to 1.76 mm. across the broadest portion. The majority are of a pinkish or flesh color, which is much lighter or absent on the under side. It was thought for a long time that the pink color was due to the larva having fed on some particular varieties of apple; but the white and pink larvæ have often been found feeding on fruit from the same tree. The head is brown in color, with darker markings, while the cervical and anal shields are much lighter. The spots in which the minute short hairs are situated are but little darker than the body wall, but can be easily distinguished with a hand lens. The mandibles are the most noticeable feature of the mouth parts. Beneath the under lip is the spinneret, from which the silken thread is drawn. The larva has eight pairs of legs. The first three pairs, or true legs, are situated on the thorax, and are three jointed. Later these form the legs of the adult insect. The five pairs of fleshy abdominal legs, or prolegs, disappear in the pupal stage of the insect. The first four pairs of legs are armed with circles of hooks, while the hooks on the two pairs at the end of the body are arranged in a semicircle. The spiracles or breathing apertures of the larva are arranged on either side on separate segments of the body. (Pl.V, fig. 1.)

ENTERING THE FRUIT.

The usual place of entrance of the first generation is by way of the calyx. The larvæ either squeeze their way into the calyx between the lobes or tunnel into the cavity at the base of the lobes. A scar, the stem, or a place where fruits touch is often selected as the place of entrance. In 1900 the writer observed an egg shell with a larval entrance hole at the edge and partly under the shell. In view of later observations it is more probable that some larva crawling around found this obstruction and entered, rather than that the larva entered the fruit directly from the shell.

The second generation for the most part enter on the sides of the fruit. The larva crawls rapidly about the apple, seeking a place for entrance. A scar or roughness is a favorite place, as the jaws slip on the smooth skin. In its wanderings the larva spins a silken thread and finally makes a web over the surface of the apple. With this as a foothold it is able to make some impression upon the skin, which is bitten out in chips and dropped into the web. Later, when it is partly covered, the larva backs out of the burrow and brings pieces out with

it. This is repeated until it is entirely within the burrow, when it turns around and spins a silken net over the hole, in which may be incorporated several pieces of the fruit. (Pl. IV, fig. 1.)

Slingerland, Card, and Cordley have also noted these larvæ enter, and the observations made by the writer agree entirely with theirs. One of the essential points noted is that while entering none of the larvæ seem to eat any of the fruit until well within the burrow, and it most probably gets some of the poison applied in spraying when it attempts to pierce the skin. The writer has observed numerous larger larvæ, and is quite positive that they do not eat any of the fruit while they are entering.

PLACES OF ENTRANCE.

The places of entrance of the successive broods are quite different. Various authors have stated that from 60 to 80 per cent of the larvæ of the first generation enter the fruit by the calyx. In 1901 several countings gave an average of 83 per cent, with a minimum of 79 per cent. In 1902 much more extensive countings gave a maximum of 93 per cent, a minimum of 50 per cent, and an average of 81 per cent. (Table III.) Less than one-half of 1 per cent enter by the stem end, while the larger remaining percentage enter the side, especially where fruits touch.

The majority of the second generation enter the side of the fruit. A few counts in 1901 showed that the greater part of the larvæ entered the side, and a few cases showed that from 90 to 100 per cent had entered at that place. Countings on 1,478 apples in September, 1902, on both sprayed and unsprayed trees, are given in Table III.

TABLE III.—*Percentage of first generation entering calyx.*

SPRAYED TREES.

Orchard.	Variety.	Date.	Stem.	Side.	Calyx.	Total.	Per cent in calyx.
McPherson	Jonathan	July 18	0	2	2	23	91.3
Do	Ben Davis	July 22	0	2	28	30	93.3
D. Geckeler	do	July 19	0	8	8	16	50
Total			0	12	38	69	82.6

UNSPRAYED TREES.

J. D. Gray		July 17	2	31	67	100	67
Do		July 19	0	38	62	100	62
Do		July 21	0	4	23	27	85.1
Do		July 25	0	7	23	30	76.6
Dr. Collister	Wealthy	July 22	0	21	236	257	91.8
McClellan		July 31	0	2	13	15	86.6
Total			2	103	424	529	80.1

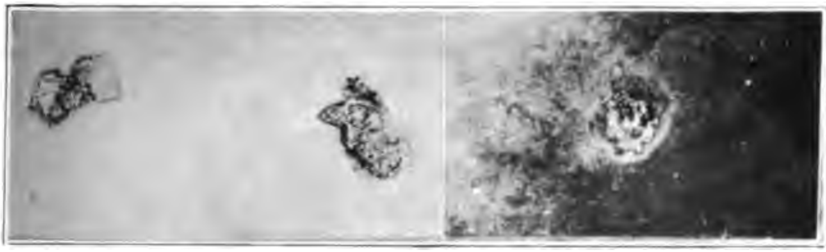


FIG. 1.—ENTRANCE HOLES OF LARVÆ OF THE SECOND GENERATION.

FIG. 2.—VIEW IN ORCHARD OF HON. EDGAR WILSON, SHOWING LOCATION OF APPLE HOUSE IN RELATION TO ORCHARD.

FIG. 3.—ANOTHER VIEW IN ORCHARD OF HON. EDGAR WILSON, SHOWING LOCATION OF APPLE HOUSE WITH REFERENCE TO THE RAILROAD.

FIG. 1.—CODLING MOTH LARVA (ENLARGED ABOUT 3 TIMES).

FIG. 2.—THE WORMHOLE OR EXIT HOLE OF THE APPLE (ENLARGED).

FIG. 3.—A WORMY APPLE, SHOWING THE FAMILIAR MASS OF BROWN PARTICLES THROWN OUT AT THE BLOSSOM END BY THE YOUNG LARVÆ (FROM SLINGERLAND).

Places of entrance of the second generation.

UNSPRAYED TREES.

Stem.	Side.	Calyx.	Total.	Per cent calyx.
4	66	57	127	44.4
5	74	31	110	28.1
12	104	76	192	39.5
4	97	41	142	28.8
1	20	12	33	36.3
1	58	14	73	19.1
27	419	231	677	[a] 26.1

SPRAYED TREES.

Stem.	Side.	Calyx.	Total.	Per cent calyx.
1	56	28	85	32
11	204	21	236	8.8
0	37	36	73	49.3
0	41	14	55	25.4
0	32	9	41	21.9
0	50	34	84	40.4
0	19	18	37	48.7
0	50	21	71	29.5
1	11	12	24	50
0	32	16	48	33.5
0	22	7	29	24.1
0	9	9	18	50
13	563	225	801	[a] 28

[a] Average.

The tables of the places of entrance of the first generation on sprayed trees show some interesting facts, and it is to be deplored that the records are not more extensive.

No definite data was secured in regard to what percentage of the larvæ enter the sides where fruits are touching. In badly infested orchards it is almost impossible to find such fruits into which a larva has not entered. It would be safe to estimate that fully 50 per cent, if not more, of the larvæ entering at the sides enter where the fruits touch.

Immediately after entering the calyx cavity the larva takes its first meal. We have a lack of data as to exactly what is eaten, but most probably the larva acts as it does when the side is entered. After spinning the web over the hole the larva, when it enters the side, eats out a cavity under the skin and throws out but little castings. This mine is eaten outward from the point of entrance, and in from 3 to 5 days the larva begins its tunnel toward the center of the fruit, reaching that point when about one-quarter grown and about a week old.

While at the surface, or while tunneling toward the center of the apple, the larva pushes its excrement and frass through the entrance hole. Later the entrance hole, especially at the calyx, is enlarged, and a considerable amount of frass is thrown out, which characterizes the infested fruit (Pl. V, fig. 3). When a considerable cavity has been made in the interior of the apple the excrement is bound together with silk. Upon reaching the central portion of the fruit the larva eats

out an irregular cavity about the core, and seems especially partial to the seeds.

The insects pass through five larval stages, and increase in size by shedding their skins four times to allow for growth. The width of the head of the larva in these different stages averages as follows: First stage, 0.38 mm.; second stage, 0.55 mm.; third stage, 0.78 mm.; fourth stage, 1.12 mm.; fifth stage, 1.6 mm. When in the latter part of the first stage and the second part of the third stage the larvæ are whitish in color, but with the cervical and anal shields black, and with blackish spots around the setæ. In the later stages the shields become brown, and the spots around the hairs are usually indistinct, especially in the pinkish larvæ.

TIME SPENT IN THE FRUIT.

Very few definite observations have been made in regard to the time the larva spends inside the fruit. Le Baron gave the time as four weeks; Riley, 25 to 30 days; Slingerland, 20 to 30 days; Card, 10 to 14 days; and Cordley, 16 to 24 days. From the nature of the case it is most difficult to get exact data on this point, as there are many accidents which may prove fatal to the experiment. On only 5 larvæ was the writer able to obtain results definite enough to use with any degree of confidence. One of these larvæ remained in the apple 14 days, two 18 days, one 21 days, and another 26 days. Professor Gillette kindly furnishes some unpublished data on this point, in which he finds larvæ to have stayed in the fruits 12, 18, 20, and 24 days, respectively, with an average of 19 days. The average of all these observations is about 20 days.

PREPARATIONS FOR LEAVING THE FRUIT.

When about full grown the larva makes a passageway to the outside of the fruit. This is usually made toward the side of the apple, in a different direction from that from the entrance hole. Rarely does the exit passage follow along or consist of the enlarged entrance passage. Before the larva has passed outside the outer portion of the passage is filled with a block of frass (Pl. V, fig. 2, *a*), or a cap of silk is spun over the hole.

LEAVING THE FRUIT.

When ready to leave the fruit the larva pushes out this block or tears away the cap of silk, crawls out on the surface of the apple, and immediately seeks a place in which to spin a cocoon. (Pl. V, fig. 2, *b*.) If the apple is upon the tree the larvæ will, in by far the greater number of cases, crawl from the apple to the twig, from there to the branch, and thence down upon the trunk of the tree. Another method, which is comparatively rare, is that in which the larva lets itself down

to the ground by means of a silken thread. This may be on account of the fact that the larvæ sometimes drop accidentally and use the silken thread to support themselves. It is not uncommon to find these threads extending through the branches of trees which are badly infested with the codling moth.

Professor Gillette finds that 85 per cent of the larvæ enter the bands during the night, and the remaining 15 per cent during the day, in August. Observations of the writer show that in the summer the larger percentage enter the bands from 6 p. m. to about 11 p. m., at Boise, Idaho. After 11 p. m. it is usually so cool that there is but little activity. In September the conditions as given by Gillette are about reversed. The nights are cold, and the larvæ are active only during the warmer parts of the day, at which times they enter the bands.

If the apple has fallen to the ground the larva simply crawls into a convenient place and spins its cocoon. After leaving the fruit the larva is unprotected, and does not consume much time in finding a place to start its cocoon.

PLACES OF SPINNING COCOONS.

In orchards the cocoons are normally found in cracks or holes in branches or trunks of the trees, under scales of rough bark, and in the rough bark on the main branches of the trees. When the trunk of a tree is smooth the cocoons are often found under bits of bark and in the earth about the foot of the trees. Cocoons are found under anything on the tree or leaning against it, as bands placed around the trunk, rags tied around the limbs, or boards and sticks leaning against the tree. When much fruit h s fallen the larvæ seem to have a greater range in spinning cocoons, often placing them among clods of earth, beneath paper or any other rubbish on the ground, in the cracks and rough bark of adjacent trees, in piles of wood or lumber, in fence posts, and under the pickets of fences. In piles of fruit in the orchards the cocoons are normally found placed among the apples; in orchards where the trunks and branches of the trees are smooth, the cocoons are often found in the cracks of the earth about the foot of the trees, and when fruit is lying on the ground they have been found among the clods of earth by Cordley and McPherson. Cordley published a photograph showing a cocoon on a clod of earth. In the writer's experience two cases have been found in which a cocoon was spun inside of wormy fruit. It was impossible to tell whether or not the larvæ which had spun these cocoons were those which had done the injury to the fruit. In packing houses it is quite common to find the larvæ in cracks of the floor, walls, and roof, in piles of lumber or boxes, and in the angles and cracks of boxes or barrels used for handling the fruit. The larva usually gnaws out a cavity in which to

spin its cocoon. These cavities are often found in the interior of rotten trees, stumps, and fence posts, with passages excavated into these rotten pieces of wood from 2 to 4 inches. In the spring cocoons can be found only in the more secure places, those spun in more exposed places having been eaten by their enemies. (See Pl. VIII.)

DESCRIPTION OF THE COCOON.

The cocoon is composed of silk, which is the product of the pair of silk glands common in many orders of insects. These glands are situated on either side of the alimentary canal, and consist of three parts, each of which has a separate function. The cephalic portions unite to form a single tube in the head of the insect, which extends to the external opening or spinneret. The spinneret is a chitinous projection on the under side of the labium or lower lip. Throughout its life the larva makes use of this silk in various ways.

When a suitable place has been selected for the spinning of a cocoon the larva begins to weave about itself this single thread of silk. The exterior outline of the cocoon conforms to that of the cavity or crack in which it is placed. While spinning the larva is bent upon itself and decreases considerably in size. When the cocoon is completed, which takes usually about one day, the larva straightens out and contracts in length. While the exterior of the cocoon may be rough, the interior is always smooth and oval in shape. At completion of the spinning of the cocoon the alimentary canal, silk glands, and other organs peculiar to the larva begin to disintegrate.

In from 1 to 19 days, with an average of about 6 days, the larval skin is shed and the insect becomes a pupa. The cast larval skin can always be found at the caudal end of the body, shriveled into a rounded mass.

Various authors have noted that when the cocoon of the codling moth is torn or cut open, it is immediately repaired by the larva. Professor Slingerland states that the damage is repaired in winter. He has also had a larva spin two or three complete cocoons after having been removed very early in the spring from the one in which it had hibernated. The writer had one spin two new cocoons during the summer. Professor Gillette notes that in Colorado the larvæ leaving the cocoons in the early spring leave those in which they have hibernated and seek other places in which to spin new ones and pupate. He reports that under 10 bands placed on the trees in the early spring 6 larvæ which were spinning new cocoons were taken.

Various reasons might be assigned for this habit of the insect. It might be that the cocoons are too deep in the wood of the trunk of the tree for the moth to emerge without materially injuring itself, or it may be that the larva on becoming active in the spring finds itself in a wet place, and, for either of these or some other reason, migrates to a better place and spins itself a new cocoon.

One of Professor Gillette's correspondents reports that he found 53 larvæ under 295 bands in two weeks. Another reports 307 larvæ April 2 and 409 April 17 from 2,500 bands. Gillette thinks that the number caught under these bands is too small to be of any great value as a remedial measure.

DURATION OF THE STAGES IN THE COCOON.

On account of the direct influence of this question upon the system of banding, particular care was taken to ascertain the duration of the cocoon stage, and especially the minimum time. The older writers gave estimates of this time with but little definite data. Riley gave from 15 to 21 days; Washburn, 3 weeks; Slingerland, 2 to 3 weeks, and Aldrich about 1 week. Professor Gillette gives records of complete experiments upon this point. In 1900 observations made for him upon 104 larvæ gave a minimum of 12 days, a maximum of 29 days, with an average of 20 days. Other experiments directed by the same writer in 1901 on 76 larvæ resulted in finding the minimum to be 3 days; maximum, 23 days, and average 16¾ days. In 1900 the writer found that in 7 cages the shortest time varied between 12 and 15 days, with an average minimum of about 14 days. In 1902 a large series of breeding experiments were carried out, the results of which are incorporated in the following table:

TABLE IV.—*Duration of life of the codling moth inside the cocoon.*

Date of entering band.	Number of larvæ.	Date moths emerged.	Number of moths.	Time.	Total effective temperature.	Average effective temperature.
1902.		1902.		*Days.*	° F.	° F.
June 29	16	July 19	2	20	433	21
		July 21	2	22	505	23
		July 22	2	23	543	24
July 14	35	July 30	1	16	494	31
		July 31	4	17	528	31
		Aug. 1	5	18	566	31
		Aug. 6	1	23	722	31
July 22		Aug. 9	2	18	583	32
		Aug. 11	1	20	645	32
		Aug. 29	1	38	1,115	29
		Sept. 1	6	41	1,170	29
		Sept. 5	2	45	1,284	29
		Sept. 9	2	49	1,392	28
July 29		Aug. 9	3	11	362	33
		Aug. 11	3	13	424	33
		Aug. 12	3	14	455	32
		Aug. 13	6	15	481	32
		Aug. 15	5	17	541	32
		Aug. 16	2	18	566	31
		Aug. 18	5	20	600	30
		Aug. 19	2	21	615	29
		Aug. 20	1	22	633	29
		Aug. 21	5	23	661	29
		Aug. 22	5	24	693	29
		Aug. 25	2	27	783	29
		Sept. 9	1	42	1,171	28
July 31	11	Aug. 18	2	18	535	30
		Aug. 19	1	19	550	29
		Aug. 20	1	20	553	28
		Aug. 21	1	21	581	28
		Aug. 23	3	23	641	28
Aug. 6		Aug. 18	1	12	209	17
		Aug. 19	1	13	224	17
		Aug. 21	3	15	270	18
		Aug. 22	4	16	302	19
		Aug. 23	3	17	330	19

TABLE IV.—*Duration of life of the codling moth inside the cocoon*—Continued.

Date of entering band.	Number of larvæ.	Date moths emerged.	Number of moths.	Time.	Total temperature.	Average temperature.
1902.		1902.		*Days.*	°	°
Aug. 6	....	Aug. 25	10	19	392	21
		Aug. 26	7	20	425	21
		Aug, 27	12	21	456	22
		Aug. 28	11	22	485	22
		Aug. 29	5	23	503	22
		Aug. 30	3	24	519	22
		Sept. 1	7	26	558	21
Aug. 13	8	....do...	1	19	468	25
		Sept. 8	3	26	674	26
Aug. 15	26	....do...	9	24	604	25
Aug. 20	28	Sept. 12	5	23	607	26
Aug. 22	25	....do...	2	21	547	26
		Sept. 17	1	26	633	24

The number of larvæ used was 170, and the stage varied from 11 to 49 days, with a weighted average of 22 days. This average is somewhat longer than that secured by other observers, and may be partly accounted for by the lateness of the season.

The principal point to be clearly shown is the length of the minimum stage, which these experiments show to be not less than 10 to 12 days.

The time spent in the cocoon by the hibernating larvæ varies considerably, but usually lasts about eight months. If the larvæ are taken inside and kept where the temperature is higher, moths will sometimes emerge in January or February.

INFLUENCE OF TEMPERATURE UPON THE DURATION OF THE STAGE.

Various authors have stated at various times that this stage might be considerably lengthened or shortened by temperature. Table V shows a preceding table arranged according to the effective temperatures and the lengths of time.

TABLE V.—*Effective temperature and length of cocoon stage of codling moth.*

Average temperature.	Total temperature.	Days.	Average temperature.	Total temperature.	Days.	Average temperature.	Total temperature.	Days.
° F.	° F.		° F.	° F.		° F.	° F.	
17	209	12	25	604	24	29	1,284	45
	224	13	26	547	21	30	535	18
18	270	15		607	23		600	20
19	302	16		674	26	31	494	16
	330	17	28	553	20		528	17
21	392	19		581	21		566	18
	425	20		641	23		566	18
	433	20		1,171	42		722	23
	558	26		1,392	49	32	481	15
22	456	21	29	550	19		541	17
	485	22		615	21		583	18
	503	23		633	22		645	20
	519	24		661	23		455	14
23	505	22		693	24	33	362	11
24	543	23		783	27		424	13
	633	26		1,115	38			
25	468	19		1,170	41			

From the table we find that the minimum total temperature is 209°, the maximum 1,392°, and the average 592°. The evidence given by this table is insufficient to warrant any definite conclusions. It is quite evident that there are other factors which have not been taken into account, of which moisture and unequal development of the larvæ when the cocoon is spun are probably the most important.

EFFECT OF THE INSECT UPON THE FRUIT.

The effect of the injury by the codling moth upon the fruit varies with the variety of the fruit and the season of the year in which the injury is done. The attack of the larvæ of the first generation usually causes the fruit to fall. A few of the fruits of fall and winter varieties, after having been injured, stay on the trees for the remainder of the season, but the early varieties fall quite rapidly and readily. In all cases the effect of the injury is to cause the fruit to ripen prematurely. The amount of the windfall of the late varieties depends in great measure upon the amount and violence of the wind.

The effect of the injury upon the value of the fruit is variable. If the inside of the fruit is eaten out, it is valueless except for use as cider apples. When the injury consists of only a small defect on the exterior of the fruit, it may be graded as second, and is of considerable value. Fruits often bear very small spots where the larvæ have pierced the skin but have failed to bore into the flesh of the apple. These spots do not materially injure the apple, and many of them are packed as first-class fruit. In cold storage apples which have been injured by the codling moth are the very first to begin to rot, and are consequently sources of contamination to the surrounding fruit.

THE PUPA.

The pupal stage of the codling moth is that stage in which the organs that are peculiar characteristics of the larva are broken down and worked over into the tissue of the adult. The pupa is about half an inch in length, and varies in color from yellow to brown, depending upon age, and when the moth is about to emerge it has a distinct bronze color. The head, eyes, mouth parts, antennæ, legs, and wings of the moth are apparent in sheaths which are immovably attached to the body. The abdominal segments, which are movable, are each armed with two rows of spines, except the terminal segments, which bear only one each. These spines point backward, and play an important part in the economy of the insect. The last abdominal segment has a number of long spines with hooks at the end. These hooks are fastened in the silk and aid the pupa in holding its place in the cocoon.

EMERGENCE OF THE MOTH.

After the pupa has thrust itself out of the cocoon, the pupal skin splits down the back, and the moth forces its way out by splitting

away the head end of the pupal skin. The legs, antennæ, and wings are drawn out of their sheaths. The insect is wet, and the body wall is soft. The wings increase several times in size, and as the body dries it grows more rigid. A few moths were observed to have emerged in the field. During the process of expanding and growing they clung to the bark of the trees with their heads up (Pl. VI, fig. 1), avoiding the sunlight. When the wings were fully expanded the moths would often hold them over their backs for a few minutes, in a manner similar to the way a butterfly holds its wings. After running about over the tree for a short time the moths fly into the lower branches of the trees, and are lost to observation. Their quick and erratic flight is similar to that of other moths of this family. The whole process of emergence takes from fifteen to thirty minutes.

THE ADULT INSECT.

The adult insect or moth is quite variable in size. The wings expand from 14 to 19 mm. Commonly speaking, they never expand over three-fourths of an inch. The whole insect is covered with scales in varying colors. The tip of the front wings bears a large dark-brown spot or ocellus on which there are two irregular broken rows of scales, which have a coppery metallic color, and with some reflections of light they appear golden. Near the ocellus there is a very dark-brown band across the wing, which is more or less triangular in outline. The remainder of the wing is crossed by irregular dark and white bands, an appearance caused by the white tips on the dark scales. In many specimens there is a distinct darker band across the wing, while in others this band is not apparent. The hind wings are a grayish-brown color, darker toward the margin, with a long black line at the base of the fringe. The underside of the hind wings has dark, irregular, transverse markings. The underside of the front wings is of a light-brown color, with opalescent reflection and with a few markings except on the costa. The legs and head and patagia are covered with long, narrow, white-tipped scales, while the body is covered with white-colored scales with opalescent reflections. The large white scales on the caudal margin of the abdominal segments are especially conspicuous. (Pl. VII.)

HOW TO DISTINGUISH THE SEXES.

There are many characteristics by which the males and females may be easily distinguished. As stated by Zeller, the males have penciled, long, black hairs on the upper side of the hind wings. These hairs are sometimes of a light color, which renders them difficult to distinguish. Slingerland discovered that the males could also be distinguished by the presence of a distinct elongate, blackish spot on the underside of the fore wings, which spot consists of a number of black scales. These

scales are sometimes of a slate color, which under certain lights renders the spot inconspicuous. There is a great difference between the genital organs of the two sexes, as the ovipositor of the female can be said to be hoof-shaped, and ends, roughly speaking, in a point; while the presence of the claspers on the male can be said to cause the abdomen to end in a line.

HABITS OF THE MOTH.

It is generally stated by writers that the adults of the codling moth are but rarely seen in orchards. In cases where the infestation is not very bad this is usually the case; but where the infestation is bad it is a very common thing to see the moths in the orchard, but never in any large numbers. They spend most of their time resting on the upper surface of the leaves or on the trunks of the trees, where they are hidden by their resemblance to the grayish bark. When disturbed, they fly away so quickly that the eye is unable to follow them in their erratic flight. According to many observers the codling moth feeds on the juice of ripe apples. The writer has often observed them drinking water in cages.

As the conclusion of many investigations by many persons and under various conditions, it has been definitely determined that the insect is not attracted to lights. A very few records of captures of codling moths at lights, usually of the accidental catching of one or two specimens, have been published.

DURATION OF THE LIFE OF THE MOTH.

LeBaron gives 1 week as the average length of the life of the adult codling moth, Washburn gives from 10 to 15 days, and Slingerland says that one moth lived in his cages for 17 days. Records of the writer in August, 1902, of forty-seven moths, show that two moths lived 1 day; ten, 2 days; eleven, 3 days; ten, 4 days; two, 5 days; seven, 6 days; one, 7 days; two, 8 days, and two, 9 days; giving a weighted average of 4 days.

The length of the adult stage depends upon the conditions under which the moths are kept, as they will live longer if there is water which they can drink. The average of 4 days was obtained when there was no water accessible to the moths; but had there been water or ripe fruit, the average would probably have been longer.

GENERATIONS OF THE INSECT.

The question of the number of generations of the codling moth in one season has for many years been in doubt. In recent years entomologists have been stimulated to greater efforts and have in a measure solved the problem. The economic importance of this question is very apparent, as the second generation of the insect inflicts about ten

times as much damage as the first generation, and it is necessary to know whether a second generation is present in order that the proper measures of control may be employed. Great biological interest also attaches to this problem, as it affords an excellent opportunity for the study of the effects of different climates on one insect.

The term "generation" is used instead of "brood" because it describes more definitely the idea intended. A generation in this connection means a number of individuals which pass through certain stages at about the same time, having begun in the same stage at the beginning of any given season. A succeeding generation is the aggregate of all the different broods of the individuals of the generation immediately preceding. A new generation is considered to begin with the egg stage, and continues through all the transformations of the insect until the moth dies. Many authors object to the term "partial generation," but as there is a condition in which this term can be used with a definite meaning, it may be well to use it. For instance, in some sections of the country all the insects pass through one generation; a few, becoming more advanced than others, may succeed in passing through the pupal and moth stages and lay eggs, from which larvæ hatch and enter the fruit, whereas the majority of the insects hibernate as larvæ and do not transform until the following spring. As those insects which enter the fruit in the fall do not for the most part complete their development, at least in the field, they are termed a partial generation.

In tabulating the results of observations in regard to the time of the various stages we find that at certain periods more individuals of a generation are in certain stages than at other times; and likewise we find periods when there are fewer insects of a certain stage than at other times. These periods are designated respectively the maxima and minima of the different generations. It is always considered that the larvæ, pupæ, and moths found in the early spring belong to the last generation of the preceding season and may be termed the hibernating generation.

From the writings of European authors we find that there is but one generation of the codling moth in northern Europe, including England (Westwood) and northern and central Germany, while the evidence of Reaumur and Schmitberger shows that at Vienna and in France there are two generations. American writers have at various times recorded many observations of variations in the number of generations in the United States. Fitch seems to indicate the presence of but one generation, while Harris says a few may transform and enter the fruit in the fall, though the majority of the first generation hibernate. Fletcher reports that careful observations extending over ten years convince him that near Ottawa, Canada, there is but one regular generation of the insect, while in the fruit-growing districts

of western Ontario there are two generations, the second being invariably the more destructive. The observations of Atkins, Harvey, and Munson agree with those of Harris. Slingerland says in 1898 that his observations indicate that in New York a large number of the larvæ of the first generation develop into moths, the percentage transforming depending upon the weather conditions of the season. In 1894 Smith found by a series of observations that the larvæ collected in midsummer did not transform further that year, but hibernated. Later, in 1897, he states that near New Brunswick, N. J., there is positively only a single annual generation, and, further, that south of Burlington County there is at least a partial second generation. In addition to the observations already given of conditions quite similar to these in New Jersey, we find that Trimble in 1865 carried out a very careful and accurate series of experiments upon the life history of the codling moth at Newark. He found that on August 10 there were three pupæ among the insects under observation, and that on August 20 many moths had emerged; on August 23 he found that one in five of the larvæ had transformed. Sanderson finds that there is one generation and a partial second generation in Delaware. He states that of the larvæ found July 31 about 29 transformed and 5 remained as larvæ. Taking these numerous observations and the data given in regard to them into consideration, we must conclude that Doctor Smith's observations are too few in number and do not justify the assertion that there is but one generation of the codling moth at New Brunswick. Many observers in widely different sections of the United States have found two generations clearly defined. Le Baron states that "in the latitude of Chicago a great majority of the moths of this brood (first) emerge the last two weeks in July." Riley, after many years of close observation, states that the insect is "invariably two brooded in Missouri." Popenoe and Marlatt found two generations in Kansas. Gillette indicates two generations in Iowa. Walton by breeding experiments discovered two generations in the same State. From a series of observations extending over several years, checked by breeding experiments, Cordley concludes that there are two generations at Corvallis, Oreg. Koebele says there are two generations in the Santa Cruz Mountains of California, and the insect probably does not differ in its habits throughout the State. Based upon one of the most extensive studies of this question that has ever been made, Gillette arrived at the conclusion that there are two generations in Colorado. Cooley says that in 1902 there were two generations at Missoula, Mont. Forbes indicates a third generation in Illinois, based upon the fact that very young larvæ were found on October 4. Coquillett states that his notes indicate that the insect has three generations in California. Washburn says there are three to four generations at Corvallis, Oreg. Card gives two to four in

Nebraska. Cockerell concludes there are three full generations near Mesilla Park, N. Mex. Aldrich in 1900 stated that there were three generations in Idaho, and in 1903 concluded after a series of breeding experiments that there was a partial third generation at Lewiston. At various times writers have made assertions that in the warmer sections of the United States a partial fourth brood was produced.

In carefully sifting all these statements the writer finds many points which throw doubt upon and render them of but little value, principally because definite dates and localities are not given. The date and exact localities are often of as much importance to future workers, and perhaps of more importance, than the observation itself.

METHODS BY WHICH THE NUMBER OF GENERATIONS MAY BE DETERMINED.

From the nature of the case the determination of the number of generations of the codling moth is a most difficult problem to solve accurately. The methods used must be scrutinized carefully, and all possible sources of error must be taken into consideration or eliminated. The correctness of a conclusion can be assured only by exactness in methods and by corroborative evidence secured by different methods. Observations made in orchard examinations have constituted one of the methods largely followed. Although observations are of great value when used in connection with other methods, they often lead to erroneous conclusions when used alone, as it is possible to obtain evidence of the condition of an orchard only from the study of a very small portion of it during a very short period. Past conditions are often unknown, and conclusions obtained are largely based upon preconceived ideas. If a large number of insects can be bred throughout the season, much valuable data can be secured and the problem solved beyond any doubt. As yet we have no records of breeding experiments carried on throughout the season with the necessary accurate data. The writer has attempted many times to breed the insects throughout the season, but has always failed, usually on account of some unforeseen difficulty which caused the experiment to end. However, it is believed that with proper care and experience this breeding can be successfully done. Breeding the insect and harmonizing the results of the breeding by observations in the orchards has been the method most used in working upon this question. By breeding the insect through parts of its generations valuable data have been secured, which, if pieced together and corroborated by other methods, are almost as valuable as if the insect had been bred throughout the season. Many entomologists have neglected to increase the value of their breeding experiments by keeping the insects under conditions of temperature and moisture different from those prevailing in the orchard and keeping no record or a very fragmentary record of the tempera-

tures to which the insects were subjected. Many other records are questionable by reason of the fact that the generation, or the nearness to the maximum of the generation, of the insects placed in the cage was uncertain or unknown.

Early in his studies of the life history of this insect the writer saw the necessity of finding some method by which the numbers of individuals of a generation could be approximated at certain times. By an incidental study of the records of larvæ captured under bands, published by Professor Aldrich in 1900, it was noted that at a certain time in the season there were fewer larvæ so caught than at periods of time immediately following and preceding. By collecting as many records as were obtainable at that time, it was observed that these conditions were quite constant. The periods of the larger and smaller number were termed, respectively, the maximum and minimum of larvæ entering bands.

In 1901 many fruit growers in Idaho, at the request of the writer, kept and submitted records of the larvæ killed under bands. Other records, many of which had been made without any idea of the future use to which they might be put, were collected from many sources. These records were tabulated and curves were drawn upon cross-section paper, using the time as one factor and the number of larvæ as the other. These curves give quite an accurate picture of the course of the insect in the orchards throughout the season. Not all of the records, however, were satisfactory, as a few of them from various causes gave data which were of no value. The curve showing the effective temperature at the dates at which the larvæ were killed under the bands was drawn upon the same charts and gives quite accurately the effect of the temperature upon this habit of the insect. A number of these records are reproduced (figs. 5 to 16).

INACCURACIES OF THE RECORDS.

There are many sources of possible inaccuracy in these records. The greatest inaccuracy is probably found in the weekly or biweekly band records, because these are composite records of many individual trees and show only approximately the dates of the maxima and minima. Many of the records were commenced too late in the season to be of any real value; and when they were started even a little late the curve ascends with rapidity, which would not have happened had the record been started earlier. In consequence of a series of warm days, the maximum number of larvæ may enter the bands sooner than they would if the temperature had remained normal; and if the temperature be low for many days, the maximum might be later than it would be normally. Spraying might seriously interfere with the accuracy of the record, as at certain periods all of the larvæ entering the fruits might be killed and thus cause a fall in the curve of larvæ entering

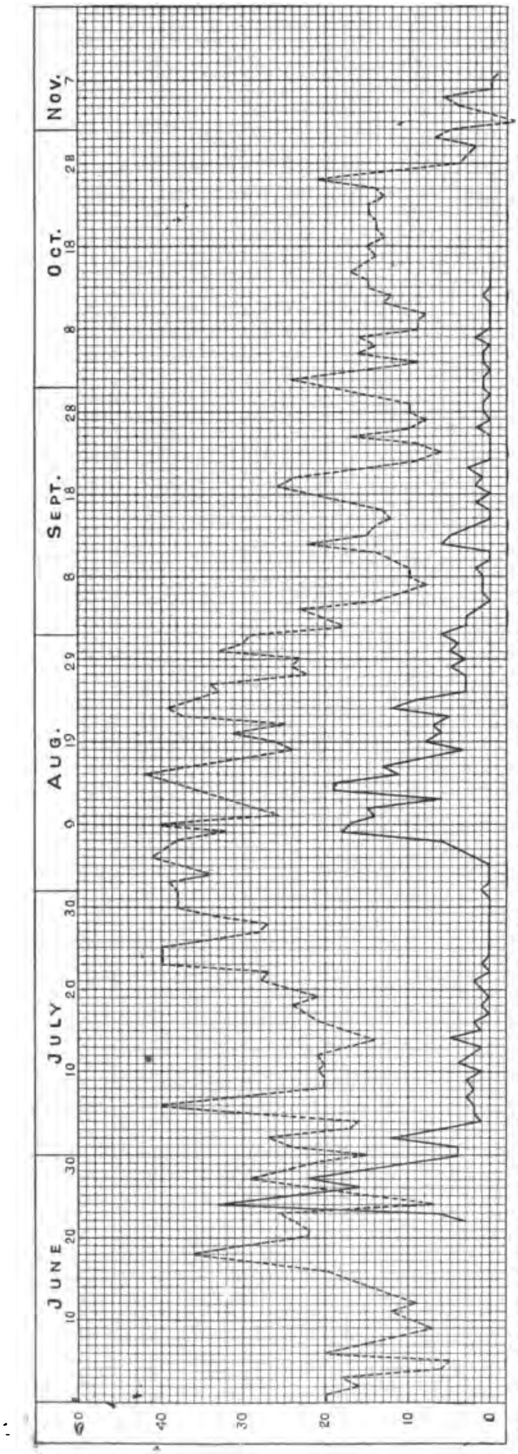


FIG. 5.—Daily band record made by H. G. Gibson, Nampa, Idaho, in 1901, upon 4 trees. (Note the relation of curve to dotted line, which indicates effective temperature.)

bands. When counted the larvæ were killed, which reduced the number of larvæ of the succeeding generation. If the tree from which the record is taken should be covered with rough bark or have a large number of holes and cracks in it, the number of larvæ entering the bands will not be so great as if the band were the only place in which they could hide to spin their cocoons; therefore, filling the holes and scraping away the rough bark would cause a rise in the curve.

In most cases the conditions which would render the records inaccurate were eliminated when it was possible to do so. In order to show the relations between the daily and the weekly band records, a weekly summary (fig. 6) was made of Gibson's daily band record. By this means it was shown that the weekly records are only approximate, and show the general trend of the insect in the orchard rather than any details. One writer has suggested that the rise and fall of the temperature would cause a corresponding rise and fall in the number of larvæ, so as to obscure the true position of the maximum. By a study of the record made by Mr. Gibson (fig. 5), in which the

effective temperature is shown by a dotted line, many interesting facts in regard to the temperature can be observed. It must be noted, however, that the number of larvæ caught on any given day is influenced by the temperature of the preceding day, as most of the larvæ enter the bands at night, some time before midnight, and that they are usually killed and counted some time the following morning, while the observations upon the temperature were taken at 6 a. m.

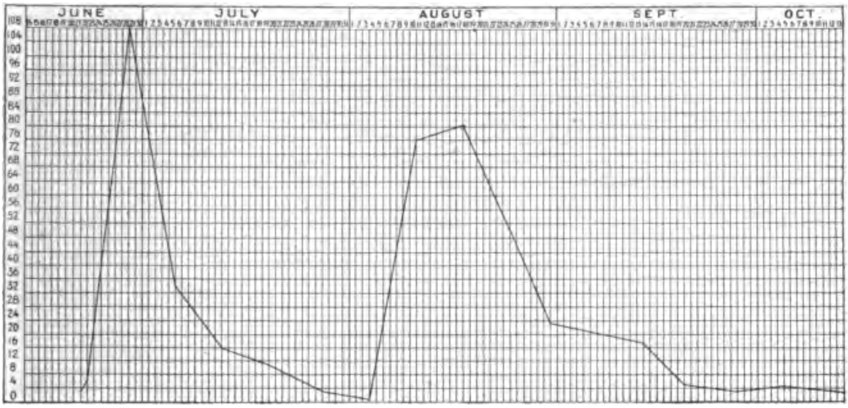


FIG. 6.—Weekly summary of Mr. Gibson's band record.

and 6 p. m. The great rise which occurred on June 24 was probably due in a great measure to the fact that the bands were placed upon the trees on the 21st. The fall in the number of larvæ on June 24, the rise on June 27, the fall on June 30, the rise on July 1 and 2, and the fall on July 4 can be partially accounted for by the corresponding rise and fall of the temperature. From about July 5 to August 4 the

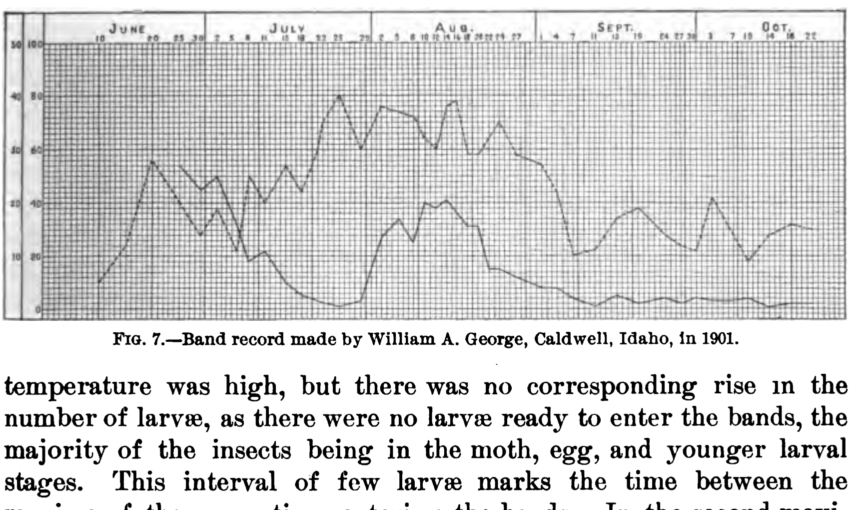


FIG. 7.—Band record made by William A. George, Caldwell, Idaho, in 1901.

temperature was high, but there was no corresponding rise in the number of larvæ, as there were no larvæ ready to enter the bands, the majority of the insects being in the moth, egg, and younger larval stages. This interval of few larvæ marks the time between the maxima of the generations entering the bands. In the second maximum it can be noted that the rise and fall of the number of larvæ is

usually parallel with that of the temperature, but toward the end of the record the temperature has but little influence. The record made by Mr. George (fig. 7) and Mr. Ayers (figs. 8 and 9) show practically

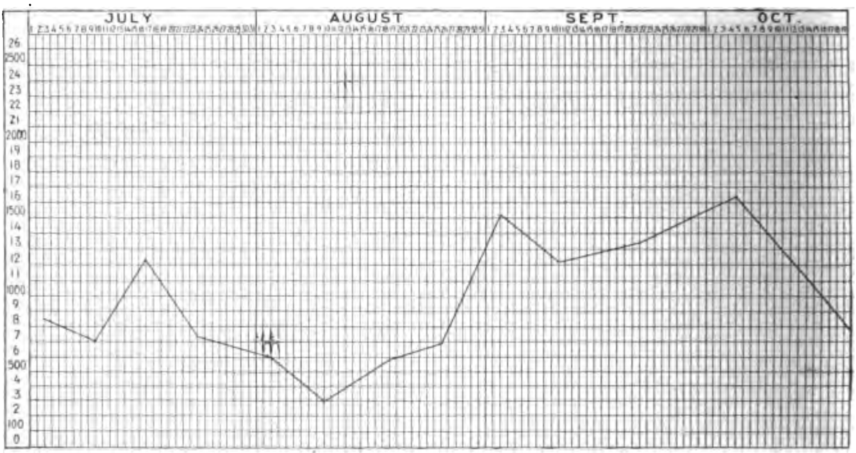


FIG. 8.—Weekly band record made by Mr. Ayers at Boise, Idaho, in 1897, on 140 trees.

the same conditions, but not so clearly, on account of the length of time between the observations.

LENGTH OF THE LIFE CYCLE.

In order to establish a correct basis for the determination of the number of generations, it is essential that we determine as closely as

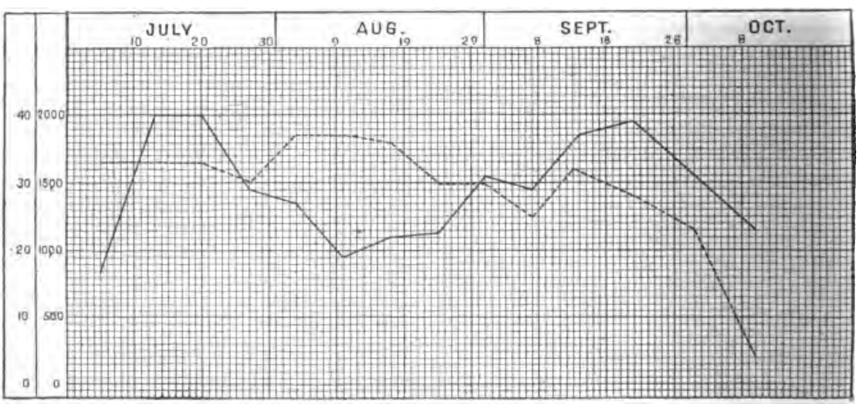


FIG. 9.—Band record made by Mr. Ayers in 1898.

possible the average number of days in which the insect can pass through one generation. Assuming a certain date, with as much accuracy as possible, when the maxima occur in a band record, and taking into consideration all the imperfections of the records, we should have approximately in the number of days between these max-

FIG. 1.—LARVÆ, PUPÆ, AND MOTHS ON ROUGH BARK.

FIG. 2.—INFESTED APPLES BEING BURIED.

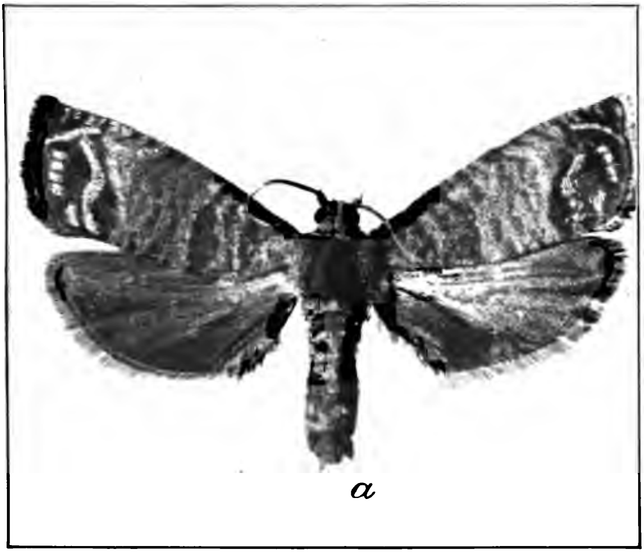


FIG. 1.—CODLING MOTH (ENLARGED 4 TIMES).
Wing on the right shows the reflections from the gold-colored scales in the ocellus.

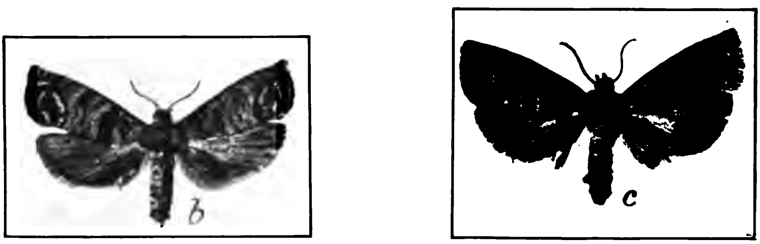


FIG. 2.—CODLING MOTHS (ENLARGED TWICE).

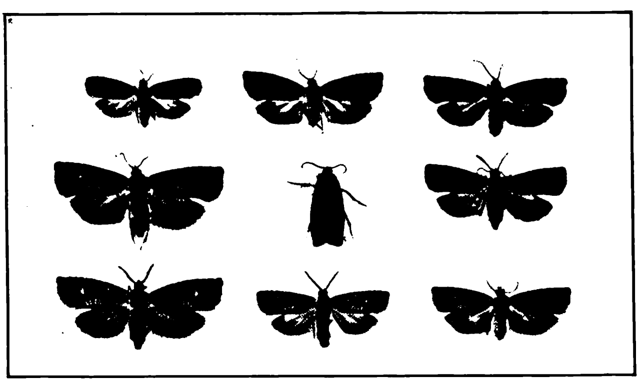


FIG. 3.—CODLING MOTHS (NATURAL SIZE, FROM SLINGERLAND).

ima the length of the life cycle of the insect. In the records given e find that the periods vary from 40 to about 66 days, with an aver-ge of 55 days, or about 8 weeks. Professor Gillette finds that according to his life history studies upon the summer brood the

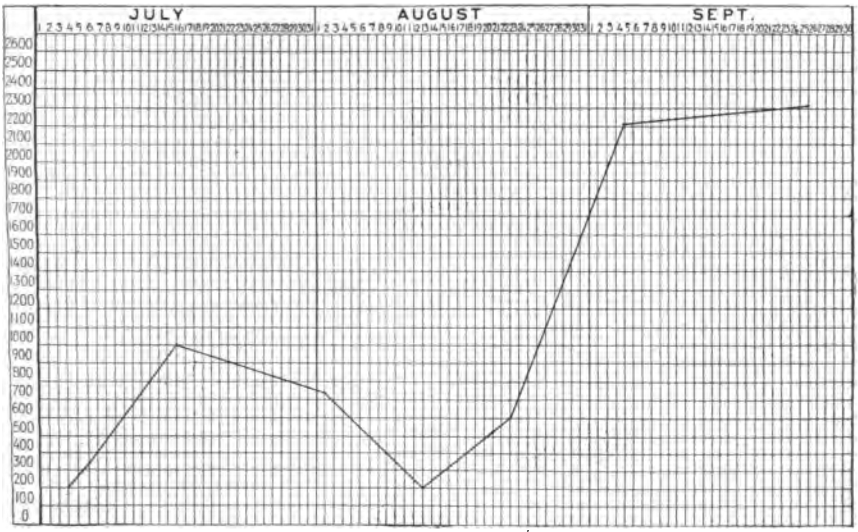


FIG. 10.—Band record made by David Brothers in Colorado in 1899.

period of the different stages is as follows: From egg to larva, 7 days; from larva to cocoon stage, 19 days; from cocoon stage to emergence of moth, 18 days; from emergence of moth to middle of egg-

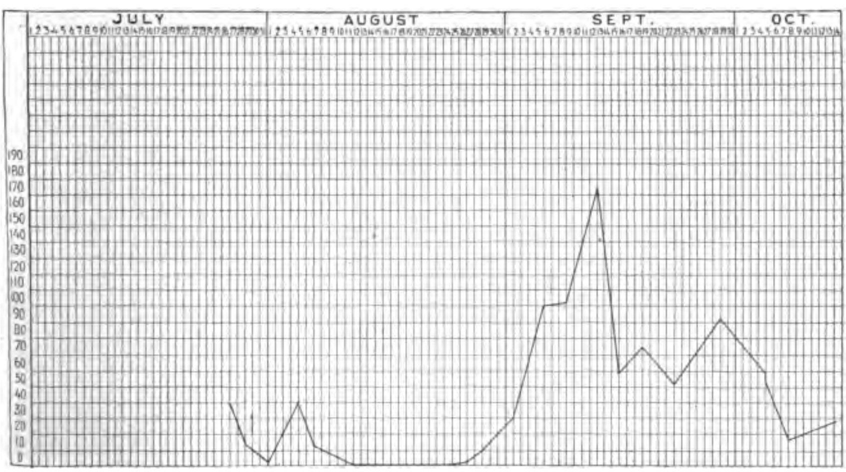


FIG. 11.—Band record published by Prof. C. P. Gillette, taken on 14 trees, at Fort Collins, Colo., in 1900.

laying stage, 5 days (estimated); total, 49 days, or 7 weeks. From the writer's numerous records of the lengths of the different stages, however, it is found that most are somewhat longer than those given

by Professor Gillette and that the egg stage averages about 11 days; from the hatching of larvæ to leaving the fruit, 20 days; from entering the bands to emergence of moth, 22 days; from emergence of moth to middle of egg laying (estimated), 5 days; making a total of 58 days, or about 8 weeks. By adding together the shortest times and the longest times, respectively, we find the minimum length of the life cycle to be 36 days and the maximum 100 days. This period of 55 to 58 days having been obtained by these two widely different methods, they are probably not far from the correct average length of the life cycle of the codling moth.

SEASONAL HISTORY.

By following the development of the codling moth through the season as carefully as possible, we are enabled to throw more light upon the question of the number of generations. Those larvæ which have escaped their enemies during the winter, if left in the field, change to

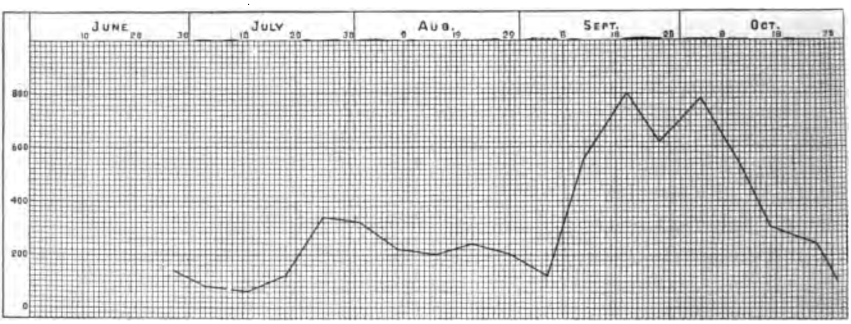


FIG. 12.—Band record made by Prof. E. A. Popenoe, Manhattan, Kans., in 1890.

pupæ, according to Slingerland, just prior to the time when the apple trees are in bloom. He found the first pupæ April 27, and by the 7th of May about one-fourth had pupated. In 1902 the writer found the largest number of pupæ about the time the apples were in bloom. Some were found in rotten wood as late as June 10. The location of the larva has the greatest influence upon the period of pupation, those in warmer places pupating more quickly than those in colder situations.

EMERGENCE OF THE MOTH.

From the records of various writers, as compiled by Gillette, we find that the first moths appeared from April 24 in New Mexico to about May 16 at Corvallis, Oreg. Mr. McPherson records that in 1901 he found a moth in the field in Idaho as early as April 23, and that the moths were most numerous about May 1. Mr. Hitt in breeding 50 moths found that the first emerged May 5 and the last May 28. In 1902 the writer found that the majority of the moths emerged between

May 15 and 20. Cordley states that in Oregon in 1899 moths emerged in some cases April 10, and continued to do so until July 1. At Ithaca, N. Y., Slingerland found in 1896 that moths emerged from May 3 to June 22, and in 1897 from May 24 to June 7. Gillette records that he found moths out of doors at Fort Collins as early as April 26. The extreme range in time of appearance of these moths was 69 days in their cages. At Fort Collins, according to Mr. Hitt's records, this period extends over about 23 days. Professor Slingerland found that this range was 49 days in 1896.

RELATION BETWEEN EMERGENCE OF THE MOTH AND THE BLOOMING PERIOD.

Slingerland states that the moths begin to emerge in New York about the time the apples are in bloom, but the majority do not emerge until after the blossoms fall, and but few larvæ are found to enter the fruit until about two weeks thereafter. Gillette found the first moth emerging about 10 days before the trees were in bloom. He states that the majority of them emerged about the time of bloom, but eggs were found July 9, 1900, and June 19, 1901, and were all hatched by July 21, the trees having been in blossom about May 5 to 15. This would make about a month between the blooming period and the time when the

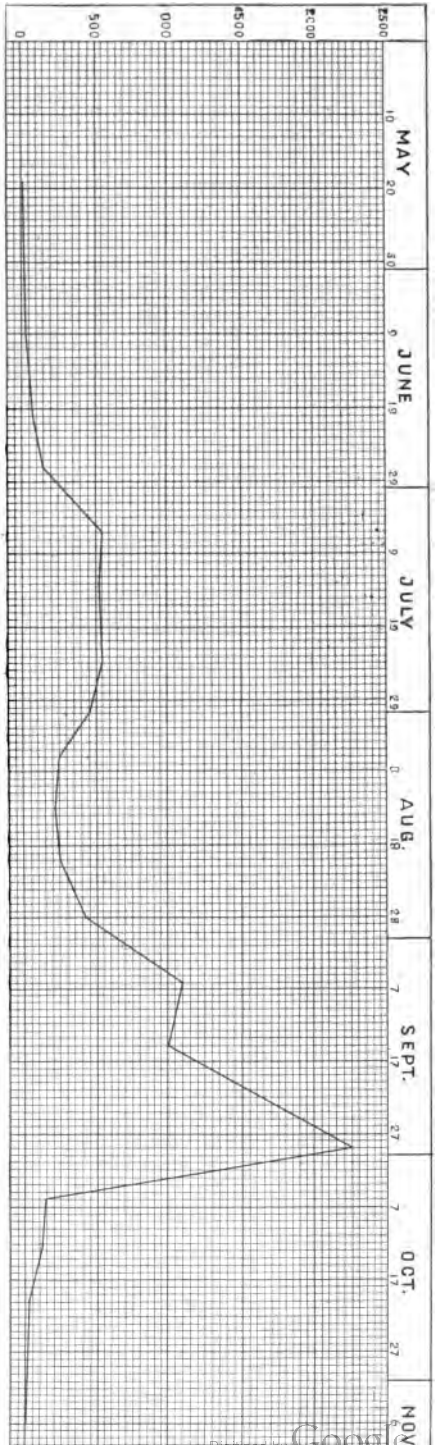


Fig. 13.—Band record made by Chapin on 850 trees in San Jose, Cal., in 1883.

first larvæ hatch and enter the fruit. Card found the eggs about three weeks after the blossoms had fallen. Cordley found that in 1898 the first larva entered the fruit about July 1, the egg from which

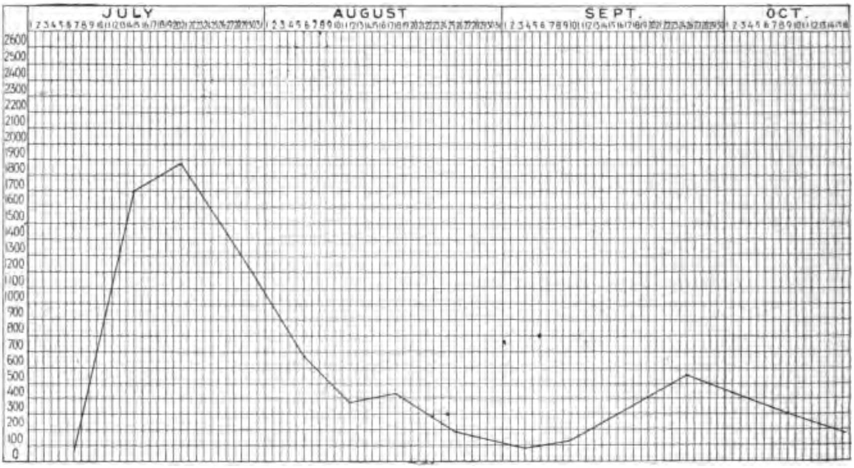


FIG. 14.—Band record made by Prof. J. M. Aldrich, Juliaetta, Idaho, on 40 trees, in 1899.

it hatched having probably been deposited about June 21. This entering of the fruit took place about two months after the petals had fallen. The writer found that in southern Idaho in 1902 the apples were in full bloom about May 13, and the first larvæ were noted to

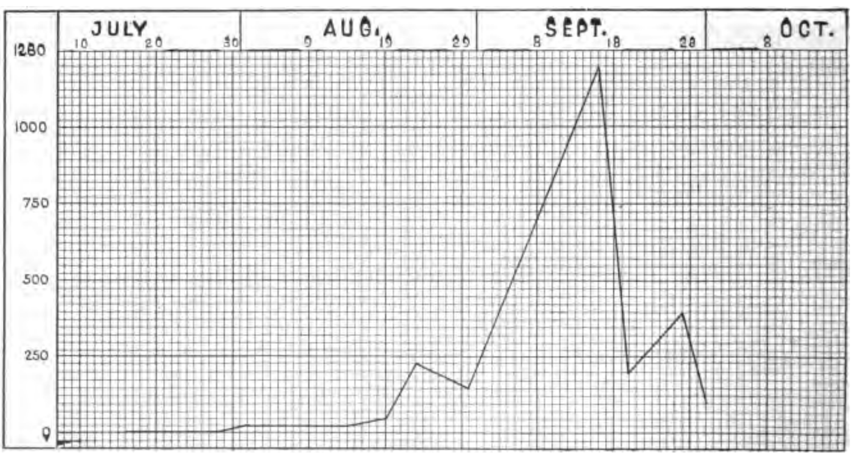


FIG. 15.—One of the records made by H. E. Burke at Boise, Idaho, in 1902, to determine the maximum of the second generation.

have entered the fruit June 11, or about 25 days after the blossoms had fallen.

From these few observations we find that the moths may emerge some time before the apples are in bloom, and, depending largely

upon locality, the larvæ begin to enter the fruit from a week to two months after the blossoms have fallen. From the standpoint of the orchardist this is a most important question in considering the effect of the first spraying upon the insect.

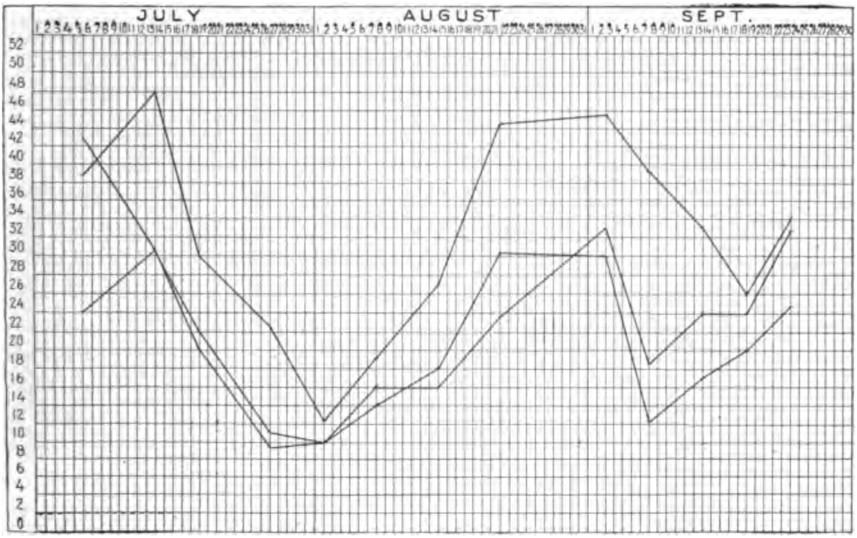


FIG. 16.—Record by H. C. Close, Utah Agricultural College.

The next point at which we can make any definite observations upon the codling moth is when the larvæ are leaving the fruit and entering the bands for the purpose of spinning their cocoons. The band records give this most valuable data in a very accurate manner. The following table shows the maximum of the different generations entering the bands, according to these records:

TABLE VI.—*Maximum of larvæ killed under bands.*

Year.	Locality.	Observer or source of record.	Number of trees.	First maximum.	Second maximum.	Days between maxima.	Total number of worms.	Time of removal of bands.	Average number of worms per tree.
1897	Boise, Idaho	Mr. Ayers	140	July 17	Sept. 15	61	12,247	Weekly	87.48
1898	....do	....do	140	July 10	Sept. 10	62	20,909	....do	149.35
1899	Juliaetta, Idaho	Prof. J. M. Aldrich	40	July 20	Sept. 24	66	8,620	....do	215.50
1901	Nampa, Idaho	H. G. Gibson	4	June 26	Aug. 16	51	467	Daily	116.75
1901	Payette, Idaho	J. Shearer	3	July 18	Aug. 17	60	215	Weekly	71.66
1901	....do	....do	80	July 1	Aug. 30	61	3,554	....do	44.42
1901	....do	....do	128	July 5	....do	56	1,690	....do	13.2
1901	Provo, Utah	Utah Agricultural College.	23	....do	Sept. 2	59	4,141	....do	180
1901	....do	....do	26	July 13	Aug. 27	45	2,829	....do	108.2
1901	....do	....do	34	July 5	Sept. 2	50	2,880	....do	84.7
1901	Hagerman, Idaho	R. E. Connor	27	July 12	Sept. 4	54	194	....do	8.2
1901	Lewiston, Idaho	S. G. Iasman	4	....do	Sept. 10	60	666	6 per month	166.6
1901	Caldwell, Idaho	Wm. C. George	10	June 25	Aug. 13	49	640	2 to 5 days	64
1899	Colorado	David Brothers	....	July 16	Sept. 15	61	......	Weekly	......
1890	Kansas	E. A. Poponoe	....	July 25	Sept. 28	65	......	....do	......
1883	San Jose, Cal	Chapin	850	July 19	Sept. 23	66	......	....do	......

Riley states that the larvæ of the first generation are most abundant about July 8; Gillette, that this occurs in Grand Junction about July 15, at Denver July 21, and at Fort Collins July 25.

MOTHS OF THE FIRST GENERATION.

Card found the first moths of this generation about July 2. Cordley gives August 1 as the date for the first and September 15 for the last. Gillette gives the following data: Grand Junction, Colo., first July 28, last September 12; Canyon City, first July 15, last September 10; Fort Collins, first July 13, last September 12. According to Gillette, the eggs of the first generation were most abundant August 12. In 1901 the writer found eggs most abundant between July 15 and August 4. In 1902 they were most abundant about the same time, but were obtained in cages as late as August 29. The dates of the maxima of this generation of the larvæ going under bands is well shown in Table VI for the second generation. An examination of these band records as published shows that the period of the larvæ leaving the fruit and entering the bands extends over two months.

HIBERNATION.

The following table by Gillette shows the time at which pupation ceased and the larvæ began to hibernate at various places in Colorado. It was found, as shown by the table, that pupation ceased between August 10 and August 30, varying with the locality in which the experiments were made.

TABLE VII.—*Proportion of hibernating larvæ taken at different dates.*

Locality.	Dates larvæ were taken.	Number taken.	Number hibernating.	Record by—
Grand Junction, Colo	July 16-23, 1900	33	1	Silmon Smith.
Do	July 24-30, 1900	53	3	Do.
Do	July 31-Aug. 6, 1900	60	8	Do.
Do	Aug. 6-13, 1900			Do.
Do	Aug. 13-20, 1900	79	78	Do.
Do	Aug. 21-29, 1900	130	130	Do.
Do	Aug. 30-Sept. 4, 1900	192	192	Do.
Rockyford, Colo	Aug. 1-6, 1900	22	5	H. H. Griffin.
Do	Aug. 7-11, 1900	14	4	Do.
Do	Aug. 12-14, 1900	51	14	Do.
Do	Aug. 15-21, 1900	66	56	Do.
Do	Aug. 22-28, 1900	115	115	Do.
Do	Aug. 29-Sept. 6, 1900	80	80	Do.
Canyon City, Colo	July 30, 1899	25	0	Dr. R. J. Peare.
Do	Aug. 1-13, 1899	70	30	Do.
Do	Aug. 14-20, 1899	50	44	Do.
Do	Aug. 21-28, 1899	100	99	Do.

Cordley has for several years been unable to breed any moths after September 15. In 1900 the writer found that pupation had ceased September 1, and in 1901 September 7. In 1902 more extensive breeding experiments were carried out, from which it was found that pupation began to grow less about August 1 and entirely ceased August 22, and that no moths emerged after September 17.

At various times records have been made of finding single moths late in the season, in October. The presence of these moths can be easily accounted for by the fact that the larvæ probably got into some place where the general outside temperature had no effect on them, and increased temperature caused transformation.

EVIDENCES OF A THIRD GENERATION.

It is often found that in September a large number of the fruits have been entered by very young insects, and it is also found that in some localities these injuries extend into October. This has given rise to the belief that there is a third generation present; and not having definite records in regard to the life history of the codling moth, many fruit growers have come to the conclusion that there are three generations, and some have even gone so far as to say that there is a partial fourth generation. Many entomologists have taken these statements from the fruit growers, and not having given as complete study to the subject as was possible, have published the conclusion that three generations were present. The writer has collected all of the publications in which three generations were either indicated or given as occurring, and has, with the greatest of care, studied the observations upon which the conclusions were based. Many entomologists have submitted original notes or copies of the notes from which their conclusions were drawn. After carefully studying all these records and published accounts the conclusion was reached that there were only two publications in which any substantial evidence is given as to the existence of a third generation of the codling moth. Professor Cockerell, in a bulletin of the New Mexico Experiment Station, concludes that there are three generations and a partial fourth. Professor Cockerell relied mainly upon observations, and checked these observations by breeding experiments in only a few instances. The observations, while of value, give the conditions in the orchard at irregular intervals, and then only for a very short period of time. Many erroneous conclusions were drawn from these observations. For instance, the finding of an empty pupa case on June 26 was considered an evidence that the moths of the first generation had emerged. In view of the fact that Professor Gillette finds that the extreme period of emergence of the moths in the spring is 69 days at Fort Collins, and that Professor Slingerland found moth in New York as late as June 22, we see that there is the greatest probability that these moths were the latter part of the hibernating generation, instead of the first part of the first generation. The finding of wormy apples on July 3 was considered as the beginning of the second generation entering the fruit. On August 12 small larvæ in fruit were considered to be the beginning of the third generation. Anyone familiar with the conditions of Western orchards knows that small larvæ entering the fruit can be

found almost any time in the summer. From the evidence given by Professor Cockerell the writer is of the opinion that there are only two generations of the insect present in Mesilla Park, and that there is no sufficient evidence of a third.

Professor Aldrich in a recent bulletin states that, in his opinion, there is at least a partial third brood at Lewiston, Idaho. This conclusion is arrived at as a result of some very carefully conducted experiments which give evidence, by breeding records, which up to a certain point is indisputable. By caging the insects at proper intervals Professor Aldrich obtained moths of the second generation on September 3 and 4. There is no doubt in the mind of the writer that these were moths of the second generation. But Professor Aldrich failed to state whether or not he obtained eggs from these moths, and instead of doing so took unknown field conditions to carry out the remainder of his experiments, taking it for granted that the larvæ entering after September 6 hatched from eggs which had been laid by moths of a similar age to those emerging September 3 and 4. As the latter were of the very earliest of the second generation, there is no reason for assuming that the larvæ which entered after this time were not larvæ of the retarded portion of the second generation. By using the length of the life cycle with the data given it is obvious that these larvæ belong to the second generation instead of a third.

CONCLUSION.

By taking into consideration the evidence which has been derived from the band records, from breeding experiments, and observation, the writer has no hesitancy in concluding that there are but two generations of the codling moth in the arid sections of the West, and that it remains to be proven that even a partial third generation of the insect is present in any part of the United States. The writer admits, however, the possibility of a partial third generation in the West and South, and that careful, accurate work in the future will give us better evidence upon this point and settle the question beyond a doubt. By a careful study of the temperatures for several years in the localities where observations have been made upon the number of generations of the insect, the writer hoped to be able to give the total temperature at which the different conditions in regard to the generations might occur; but after a great amount of labor this was found to be impracticable, principally on account of insufficient accurate observations upon the insect, and it was decided to make use of the more general life zones in determining the distribution of generations. It may be stated that the boundaries between these life zones are only approximate; that there are different gradations between them, and that as yet there are many inaccuracies in the map. Mr. Marlatt, from personal experience and the observations of other ento-

mologists, arrived at the conclusion that there was one generation of the insect in the transition zone, two in the upper austral, and three in the lower austral. By using the conclusions of recent years the writer finds that there is one generation in the transition zone, with often a partial second, two generations in the upper austral, and two in the lower austral, with a possibility of a partial third.

NATURAL CONDITIONS WHICH TEND TO DECREASE NUMBERS.

It has often been noted that a sudden fall of temperature is fatal to a large number of the smaller larvæ of the codling moth. It has been already noted that Professor Aldrich has recorded such an observation. Hot sunshine and extreme dryness cause many of the pupæ in the case to die. A moist climate aids fungi and bacteria to such an extent that sometimes most of the larvæ are killed by them. Larvæ that are killed by fungous diseases are hard and mummified, and have a whitish appearance. Bacteria cause the internal organs to disintegrate and the larva to become limp and full of juices of a brown color.

NATURAL ENEMIES.

Although the codling moth has many natural enemies, the number as compared with those of other Lepidopterous larvæ is comparatively small. This may be accounted for by the fact that the insect throughout the greater part of its life is more or less protected, but when the larvæ have left the fruits and are seeking places in which to spin their cocoons and when in the winged stage they are attacked by numerous enemies. Birds are by far the most efficient natural enemies of this insect. Anyone who tries to collect the larvæ from the trunks of trees in spring will find very few specimens, but, on the other hand, will find many empty cocoons. The writer has many times in the spring searched persistently for larvæ in the rough bark and the more exposed cracks, but found practically none, although many could be secured by cutting into the holes and cracks of the tree. Riley, Walsh, and Slingerland also note this effectiveness, and the amount of good the birds do can only be estimated. The cocoons are always found, and on a close inspection of the bark a telltale hole discloses the story of some woodpecker's work. It has often been noted also that the same birds have made holes or enlarged the cracks in the stubs of old branches for the purpose of digging out the larvæ. Plate VIII, figs. 1, 2, 3, shows stubs of branches from an old orchard near Elkton, Md., in which these birds have done efficient work in reducing the number of larvæ during the spring. Fig. 2 is especially interesting, as on close examination it shows the following points: Some time in 1900, in the course of pruning the orchard a branch was cut away, leaving the stub, which is 8 inches long. In the following winter and

spring the stub began to crack and decay and the bark to loosen. Many codling-moth larvæ crawled under the bark in the fall of 1901. The woodpeckers found this stub in the following winter and spring, and not only probably secured all the larvæ which were under the bark, but enlarged one of the main cracks in order to get those which were hidden inside. In the fall of 1902 all the bark had fallen from this stub and many more larvæ took refuge in the cracks. Upon examination, in May, 1903, the writer found that the crack had been recently enlarged, as is well shown in the reproduction. This recent enlarging was probably done mostly by the pileated woodpecker (*Ceophelus pileatus*), as the chips broken out were quite large, and probably required more strength than other smaller woodpeckers could muster. This stub was sawed from the tree and sent to the writer, and in the latter part of May the moths emerged, and 28 empty pupal skins were found on June 25. The writer estimates that fully 100 larvæ hibernated in this stub.

It is highly probable that all woodpeckers feed on the codling moth larvæ. Other birds, including the nuthatches, black-capped titmice, wrens, bluebirds, crows, blackbirds, kingbirds, swallows, sparrows, chickadees, and jays, may also feed upon the codling moth, especially those birds which winter in the locality where the larvæ are present. Without doubt the bobwhite quail, which has been introduced into many sections of the West, also feeds upon this insect. At best our knowledge of the food habits of many of these birds in regard to the codling moth is based upon but little direct evidence; but reasoning from what we do know positively, there is little doubt that codling moths form a part of the diet of at least some of these birds. Not many years ago a movement was set on foot in the Pacific northwest to import the German kohlmeisen into this country, as it was said to feed largely upon the larvæ of the codling moth; but because the benefits derived from the bird in its native home were not clearly proven, and that it sometimes injured fruit, and also on account of many disastrous experiences in the importation of birds and mammals which have already been made, the majority of the authorities were convinced that it would be a dangerous experiment, and no further action was taken. The expenditure of time and money necessary to carry out such a project would probably be more beneficial if applied to the protection of our native birds.

Koebele writes that in California he knows of many small bats flying around the apple trees in the evening, taking moths on the wing, and even darting down to take moths which were upon the leaves. The writer has often noticed bats flying about the apple trees, but was unable to obtain any evidence that they were catching codling moths.

INVERTEBRATE ENEMIES.

The writer has often found moths in limb cages dead with spider's silk wound around them, but made no further observations. The insect enemies of the codling moth are either predaceous or parasitic, and are quite numerous as to species, but are usually few as to individuals. A large number of predaceous insects in the larval stage have been observed feeding upon the codling moth, the following list being compiled from publications of various authors:

Chauliognathus pennsylvanicus.	*Pterostichus californicus.*
Chauliognathus marginatus.	*Calathius rufipes.*
Telephorus bilineatus.	Dermestid.
Trogosita corticalis.	Clerid.
Trogosita laticollis.	Chrysopa.
Trogoderma tarsalis.	Raphidid.
Perimegatoma variegata.	

In regard to many of these predaceous insects it is doubtful whether they feed upon the living codling moth larva or upon dead specimens. At best, they do not reduce the number of the larvæ to any considerable extent. In Utah a species of Ammophila was found stocking its burrows with larvæ of the codling moth. It is also recorded in California that *Sphecius nevadensis* was found pulling the larvæ out of their burrows.

Many observers have found the eggs parasitized by a species of Trichogramma. Even in its protected life the larva is preyed upon by many parasitic insects, among which are the following:

Goniozus sp.	*Pimpla annulipes.*
Macrocentrus delicatus.	*Bethylus* sp.

The writer found traces of three species of parasitic Hymenoptera which were preying upon the codling moth in the Pacific northwest, but was unable to breed any of them. Among the Diptera only one parasite is mentioned, namely, *Hypostena variabilis.*

In general it may be said that these parasitic insects are found in such numbers to be of value only in neglected orchards, and in any orchard that is well taken care of, sprayed, banded, and otherwise treated in preventive and remedial ways, these predaceous and parasitic insects are found in very small numbers or are entirely absent.

Even with the host of enemies arrayed against it, the codling moth under normal conditions in the West will ruin practically all of the apple crop, and if success is to be obtained proper measures of control by human agencies must be instituted, and the parasitic and predaceous enemies left out of the question, except woodpeckers, which may be encouraged with profit.

HOW TO COMBAT THE INSECT.

The codling moth seems to have been present and injurious in orchards for centuries, but until about eighty years ago no one seems to have made any suggestions as to how its ravages might be checked. It would require volumes to contain all that has been written about the methods which have been used against this insect—most of them valueless. Before considering methods of combating the insect there are several points which must be discussed.

Many of the Western States have horticultural laws which aim at extermination, and many of the corps of inspectors are working with that end in view; others, however, from recent experience have been led to change their views upon the subject. When one discusses the extermination of an insect he ventures upon debatable ground. As yet no insect has been exterminated through the agency of man, and judging from past experiences the writer believes that it is impossible to exterminate the codling moth even in a single orchard. The control of it, by means by which the damage it inflicts is reduced to a minimum, is the very best that we can expect to accomplish. It is a prime necessity, in order to make recommendations of value, that the entomologist have an accurate knowledge of the life history of an insect. Not only is this necessary for the entomologist, but it is essential for the fruit grower also to understand it, in order that he may apply recommendations intelligently and vary them to suit conditions. The erroneous ideas some fruit growers have upon the life history of the codling moth are sometimes startling, following recommendations simply because they are given to them, and having no idea of the reason therefor. Often they obtain good results, but more often failures result; and as they do not understand the reasons for the recommendations, they are at a loss to know why they did not obtain good results. To combat the insect successfully the fruit grower must be familiar with all the stages of the insect, the sequence of the stages, where found, and habits and variations. He should also be informed how the preventive and remedial measures act in reducing the numbers of the insects. With this knowledge he will be able to vary the recommended preventive or remedial measures to exactly fit his local conditions, and if any failures occur he will in a measure be able to tell why they occur, and the following year the experience will aid him in changing his methods in order to obtain better results. He will also be protected against using methods which are of no value, and will thus avoid a large unnecessary expense.

PREVENTIVE MEASURES.

Preventive measures are those which not only aid in controlling the codling moth, but aid the fruit grower in training trees so as to bear more fruit, support it while growing, and produce fruit of a better

quality, size, and color. Although many of these questions are not closely allied to the control of the codling moth, they are of importance, as anything which increases the margin of profit aids in securing better general results from an orchard.

There are many methods of prevention which may be applied to keeping the insect out of a section of the country in which it is not yet present. By study of the means of its spread it will be learned how it may have entered the country, and by closing all possible avenues of introduction immunity may be secured for many years; but if fruit is being continually shipped into a new country from an infested district, it is only a question of a few years when in spite of all that can be done the insect will gain a foothold. Whether it becomes injurious or the loss is nominal will depend upon many conditions.

Many orchardists who have planted young orchards in infested districts are quite desirous of keeping the codling moth out of their orchards as long as possible, but if there are infested orchards near by this is a practical impossibility. It may be said that money and labor spent in keeping the insect out of a section or an orchard will accomplish more good if directed toward the study of better orchard methods and adapting the measures of control to that section of the country.

To insure the best results in the planting of a young orchard in an infested locality the codling moth should be considered from the very first, and everything that is done should be done only after taking into account the actual or probable presence of the insect. If note is taken of these methods and they are faithfully carried out, a great amount of labor and loss will be saved when the orchard is in bearing. There are many questions which can be decided for each locality only after all the conditions over which the fruit grower has no control, such as transportation, exposure, temperature limits, and proximity to water, have been fully considered. Although the question of soils is very important, by appropriate methods the character of some soils can be materially changed, as by cultivation, cover crops, and other means. The first question which confronts a man wishing to plant an orchard is the question of varieties, which is one of the most difficult problems to be solved. The soil, the climate, the purpose for which apples are grown, and various other factors, must be considered, each one having its own bearing upon the problem. If a home orchard, the likes and dislikes of the grower are the first consideration, but if the aim is to plant and maintain a commercial orchard, the question of varieties must be determined, first, by finding what varieties are well adapted to the locality in question. This can be learned by consulting the experiment station officials in the different States and from the experience of growers who have orchards in that locality. The next consideration is what varieties will meet the market demands and com-

mand the highest prices. It is a well-known fact that in the arid regions of the Pacific Northwest the Jonathan, Grimes Golden, Rome Beauty, Ben Davis, Winesap, and a few others are the best adapted to a commercial orchard; while in the humid sections of the same region the Newtown Pippin, Spitzenberg, and a few others have proven most successful. It might be well to note here, as has been stated before, that the Pewaukee and Ortley apples are always found worst infested with the codling moth, while the Lawyer and Winesap are least infested.

After it has been decided which varieties to plant, the next question is that of buying the stock. Good stock should always be insisted upon, and one can be sure of securing the desired varieties only by buying from well-established, conscientious nurserymen. It is preferable in the arid region of the Northwest to plant 1-year-old stock. The land usually has some vegetation upon it, such as sage brush or timber, and after clearing it the soil should be thoroughly pulverized. If irrigation is intended, the ground should be leveled and graded to facilitate irrigation. The courses of the irrigation ditches should be determined by the general contour of the land, taking into consideration the future routes of the spraying machine, which will draw upon these ditches for water for spraying.

SETTING THE TREES.

There are many methods which may be used for setting the trees, the details depending on the size of the orchard and the means at hand. The essential feature of the operation is to make the holes large enough to receive the roots of the tree, so that they can still retain their natural position. After filling and packing earth into the holes, water should be allowed to run in, to aid in giving the trees a good start.

It has been found that it is a very injurious practice to place any manure in the holes when the tree is planted. If manure is to be applied in the new orchard, the best method is to scatter it over the surface of the ground.

Care should be taken to cause the trees to lean toward the southwest, from which the hottest rays of the sun come. By doing so, sun scald will in a great measure be avoided. After sun scald the bark breaks, and the wood is exposed and becomes cracked and decayed. It has often been found that trees thus affected always bear a larger percentage of wormy apples than trees on which the bark is unbroken. This is accounted for by the fact that the codling moth larvæ go into the cracks to spin their cocoons and are there secure from their enemies.

It is a common sight in all sections of the country to see trees planted from 16 to 18 feet apart, with the upper branches intermin-

gling so as to form a dense mass of branches which can not be sprayed properly, and there is no room between the rows for wagons or cultivators. It is strongly urged that the trees be set not closer than 30 feet apart; some growers prefer 40 feet.

PRUNING.

No arbitrary rules can be made for pruning on account of the fact that every kind of tree and plant, in fact every individual, presents its own peculiar problem; but there is an ideal which the pruner should endeavor to attain. It is found in many sections of the West that the trees have been allowed to fork so that there are two or three main branches, and upon bearing a heavy crop these branches have split apart, sometimes totally ruining the tree. At best, if the branches are brought back into place and held by bolts, wires, or ropes, a crack will be left, into which fungous diseases can enter and in which codling moth larvæ will spin their cocoons. Such a break should be dressed with grafting wax or shellac varnish, and the branches fastened closely together. With proper pruning, when the head of the tree is being formed, this trouble may be avoided. Instead of two or three main branches, the head of the tree should be so formed as to have four to six, thus distributing the weight, and preventing breakage under ordinary conditions.

Many apple growers have headed their trees too high for best results. The disadvantages of this method are that it is difficult to reach the fruit and foliage with spray, and much more difficult and expensive to harvest the fruit. Other growers have headed their trees so low that the branches spread and droop so that they are close to the ground. In many instances when there is a heavy crop of fruit these branches bend down and either touch or lie upon the ground. The result is that much of the fruit on the interior of these trees and on the under sides of the outer branches is so shaded by the foliage that the sunlight can not reach it, and a large percentage will be poorly colored and of second quality. (See Pl. IX.)

A mean between this high and low heading is to be desired, which will do away with most of the disadvantages of these extreme methods. In order to secure proper coloring in fruits on trees it is necessary that enough smaller branches be removed to admit an abundance of sunlight through the tops.

In the arid sections of the Far West the trees grow with great rapidity, and if allowed to take their natural course become slender and not strong enough to support a normal weight of fruit. It has been found that by cutting back half of each year's growth the trees will be made to grow heavier and stockier, and thus be able to support the weight of a large load of fruit without any danger of breaking.

IRRIGATION.

Proper irrigation of the orchard depends entirely upon the conditions. There are several methods of employing water in irrigation—by flooding, by a system of checks, or by furrows. The latter is probably the most efficient, but care should be taken that both sides of the tree receive an equal supply of water.

SOIL OR COVER CROPS.

The soil of different localities varies, and the treatment should vary with the conditions. In irrigated sections the soil is usually lacking in humus, and is often packed so closely together that it is impervious to water. By proper tillage this is corrected to some extent, but the greatest success has been attained by growing cover crops. Red clover is successfully used for this purpose, and is advantageous in many ways. The roots penetrate deeply into the soil, thus forming passages for water; by keeping a cover of clover over the soil, evaporation from the soil is retarded, and the irrigation need not be so frequent, as the water is retained for a longer time; the clover can be cut and used for hay; and about every third year the practice of plowing the clover is followed, so that, in addition to the fixing of nitrogen by the roots of the clover, the decaying vegetation adds needed humus to the soil.

ORCHARD IN BEARING.

A very serious error is made by many fruit growers in regard to the first crop of fruit. Reasoning that the first crop is not worth trying to save from the codling moth, the grower allows the insect to infest most of it, intending the following year to apply preventive and remedial measures and put it under control. The result usually is that the following year he has an abundance of insects, and his loss will be considerable. If, when the larvæ were all in this first crop, the apples had been destroyed by being picked and buried, or if bands had been used late in the summer, a large percentage of the loss in the second year could have been prevented.

It is often the case that on account of some unforeseen condition, such as a freeze or a frost, the fruit crop is reduced to almost nothing. Under such conditions each grower must decide for himself what methods he will pursue. Usually in such years the price of fruit is very high, tempting the grower to produce all the fruit he can, even if infested. The writer recommends that when the crop is so small that each tree will produce only about one box or less of good fruit, the fruit should be picked and destroyed, not earlier than the middle of July nor later than the middle of August, and other methods such as banding should be used to destroy as many of the remaining insects as possible. Various instances have been under the observation of the writer in which these suggestions were followed with great success.

Fig. 1.

Fig. 2.

STUBS OF BRANCH CUT FROM A TREE, SHOWING WORK OF WOODPECKER.

FIG. 3.—STUB ABOUT 8 INCHES LONG, SHOWING WORK OF CODLING MOTH LARVÆ AND WOODPECKER.

Twenty-eight moths which the woodpeckers did not get emerged from this piece of wood.

STUBS OF BRANCHES FROM AN OLD ORCHARD NEAR ELKTON, MD.

VIEW IN ORCHARD OF HON. FREMONT WOOD, NEAR BOISE, IDAHO.

Showing 8-year-old Jonathan tree heavily loaded with fruit. (From photograph.)

There are many preventive measures which may be applied to the orchard when it is in bearing.

It is a well-known fact that an orchard which produces a moderate crop each year is much more profitable than one which produces an abnormally large crop one season and a very small one the next. By thinning each year this alternation may be prevented to some extent.

The writer is very strongly of the opinion that if thinning is done when the larvæ of the first generation are in the fruit, and the fruit and larvæ destroyed, the advantages thereby gained are sufficient to compensate for the expense of thinning.

It is easy to see how the destruction of part of the first generation will prevent much of the injury due to the second generation, which is about ten times that by the first generation. It is difficult for the orchardist to determine by observing the entrance holes about what time the insects are inside the fruit. In thinning, all terminal clusters should be reduced to one fruit, and none should be allowed to grow closer together than from 4 to 6 inches. During the process of thinning, with but little increased expenditure of time or money, the wormy fruits can be removed and the perfect left on the tree.

Throughout the season a large number of fruits will drop from the tree to the ground. Upon examination it will be found that under normal conditions the larger percentage of these are the result of the work of the codling moth. The percentage varies, however, with many conditions. If a tree is heavily loaded, a large number of good fruits will be pushed off by those adjoining, and the wind will cause many to fall. The quantity of windfalls increases throughout the season.

The percentage of the larvæ to be found inside the wormy fruit varies with the time of the year. In the Pacific Northwest the latter part of June and the first part of July and the latter part of August are the times when the largest number of larvæ are found inside the wormy windfalls. In a small orchard these windfalls can be destroyed by allowing hogs to run at large in the orchard and eat the fallen apples; or the windfalls may be picked up every few days and either made into cider or destroyed. In a large commercial orchard, however, it is not probable that the expense of keeping the ground clear of windfalls would be justified by the benefits derived, although such benefits would undoubtedly be great.

PREPARING FRUIT FOR THE MARKET.

The method of packing which is now coming into use is to pack the fruit in the orchard, using packing tables built upon runners. These are hauled down a row, stopping at intervals. Two rows are picked on either side of the table, and the fruit is carried from the trees to the tables by the pickers. The fruit is there graded and packed, and

the culls are left in piles in the orchard. The advantages of this method of packing are many. The fruit is handled but once, and is not hauled any distance until it has been securely packed, and the danger of breaking the skin or bruising is reduced to a minimum. The picking and packing crews also work as smaller units, and can be more easily directed and do far better work. The codling moth larvæ in the culls, after completing their development, will, if allowed to do so, spin their cocoons among the apples in the piles. (See Pl. XVI.)

Fruit may be well grown, well colored, and of proper varieties, but if not well packed these conditions are nullified. Apple growers in the Far West are confronted with rather special problems. By reason of their distance from the large markets of the United States, the price they would receive for second-quality fruit would hardly be sufficient to pay the expense of growing, packing, and shipping, and it is incumbent upon them to ship nothing except that which is strictly first class, packed in strictly first-class manner. The cost of transportation, prevailing market price, and size of crop, however, must be taken into consideration.

The methods of packing depend upon the kind of package used. Eastern grown apples are usually packed in barrels. From Colorado and Montana westward boxes containing either 40 or 50 pounds are almost universally used. Some are even going further, using small packages containing half bushels of superior fruit. There are many methods of packing the fruit in these boxes, as may be required by the purchasing dealers. In all cases it is highly essential that the fruit be packed so tightly in the box that there can be no shifting of position while in transit; that there be a decided swell in the boxes on both top and bottom if they are made of thin and flexible wood, as is usually the case in the West; that the paper lining of the box remain unbroken, and that when the fruit is opened it will be attractive to the buyer.

The more progressive fruit grower is well aware of the fact that a reputation for first-class fruit can be obtained and secured only by packing such fruit and rigorously excluding all wormy or scale-infested apples. Although it is extremely difficult for a packer to put up a box of apples containing not a single wormy fruit, it should be firmly impressed upon his mind that is the ideal to be attained.

The second-quality apples, which are usually disposed of in the local markets, are those but slightly injured by the codling moth, or undersized or uncolored. The culls and windfalls should be piled together and disposed of as quickly as possible. They may be either fed to stock immediately or made into cider for vinegar. The value of these culls is considerable, and progressive orchardists count a good deal on the revenue derived from them. From the seconds, culls, and windfalls in one orchard with which the writer is familiar

5,000 gallons of cider were made, which sold for as high as 20 cents per gallon. One bushel of apples made from 2½ to 3½ gallons of cider, by means of a hydraulic press run by the gasoline engine used in spraying.

If it is not possible to dispose of the culls otherwise, they should be buried in holes in the orchard and covered over with 6 to 8 inches of closely packed earth. (Pl. VI, fig. 2.) Occasions may arise when it is necessary to store these for some time, although the storing of such fruit should be avoided if possible.

Fruit should be stored in a house in which there are no holes or cracks in the roof or walls. When the larvæ inside the fruit have completed their development they spin cocoons and transform into pupæ, which in turn transform into moths. These moths emerge, and if there are cracks or holes in the house they will escape and fly to the orchard the following spring. If, however, the house is tight it may be fumigated; or, better still, screens may be placed over the windows, and as the moths collect upon these screens, they may be crushed, or they will die if left a week or so.

The writer studied two cases in Idaho in which apples were stored quite near an orchard. (Pl. IV, figs. 2 and 3.) The effect was that the following year the part of the orchard nearest the apple house was always most infested, and in spite of all the remedial measures applied there was a great amount of damage. In California it was found by Mr. De Long that in a house in which apples were stored the moths always emerged and went to the windows. Records were kept of these insects, and it was found that 11,974 moths were killed from April 15 to August 12. One can easily imagine what destruction these moths would have caused had they been allowed to fly to the orchard.

PREVENTIVE MEASURES IN OLD ORCHARDS.

In all sections of the country old neglected orchards are easily found in which practically all of the fruit is infested by the codling moth. The writer is quite familiar with two typical orchards, one of which is situated in an irrigated section of the far West and the other in a humid section of the East. Although the climatic and other conditions are quite different the two orchards have many features in common.

The western orchard consists of about 300 trees about 18 or 20 years old, planted about 16 feet apart each way. The branches of each tree touch those of the surrounding trees so as to form a dense mass of branches and foliage. Theformer owner of the orchard, finding that the codling moth destroyed the larger part of the fruit, gave the orchard no irrigation, and in consequence the trees are in a more or less stunted condition. The branches are thickly matted together, having never been pruned. The trunks and branches of the trees are

covered with rough scales of bark, and where branches have been cut away the stubs remain, with irregular cut ends, the branches having been hacked off with an ax. These stubs have in many places cracked and begun to decay, thus making excellent places in which the larvæ of the codling moth could spin their cocoons and hibernate. The writer once secured 20 larvæ from the holes and cracks in one of these stubs. The cut ends were not given proper dressing and decay has taken place, often leaving large holes in the trunks and branches. Many cocoons can be found in this rotten wood, and on all the trunks and branches one can find numerous empty pupal skins from which moths have emerged. The soil of the orchard has received no cultivation and is covered partly with weeds, principally prickly lettuce. The orchard is very productive and always bears a good quantity of fruit, but, being undersized and from 90 to 98 per cent infested by the codling moth, practically no revenue has been derived from it for the past five or six years. In 1900, 1901, and 1902 the writer searched carefully for uninfested fruit, and each time found on the tree near the trunk only a dozen or so small stunted apples which had escaped the codling moth. Other insect pests are present in this orchard, each requiring special treatment.

The eastern orchard is situated in a good horticultural region. The trees number about 300, and are probably about twenty-five years old. They are placed 40 feet apart, and have made a good growth. The trees have received some pruning, but as in the western orchard there are many stubs left, and there are numerous decayed holes in the trunks and branches. In many trees the branches are matted together and shade the fruit. The soil is in fairly good condition and lightly sodded. Until the past two or three years the orchard has been remarkable for its productiveness, but a large percentage of the fruit was small and much the larger part of it was infested with the larvæ of the codling moth.

The treatment that these orchards should receive to bring the codling moth under control is about the same. It may be stated that if the preventive measures advised for a young orchard had been faithfully and intelligently carried out many of the existing conditions would not have been present.

TREATMENT OF OLD ORCHARDS.

The first thing to be done to old orchards is to prune the trees in such a manner that the sunlight and spraying solutions will have easy access to the foliage and fruit. Every other tree in the western orchard should be cut down. The stubs of branches should be sawed off close to the trunks and burned in order to destroy the hibernating larvæ contained in them, and the cut ends remaining on the tree covered with shellac varnish or grafting wax. The holes in the trunks

and branches should be filled with cement, plaster, or clay, in order that the insects inside may be confined and die, and that other larvæ later in the season will be unable to enter to spin their cocoons. The rough bark on the trunks and branches should be scraped away and burned.

In both of these orchards it is a noticeable fact that the woodpeckers have been very efficient in digging out the hibernating larvæ. (Pl. VIII.) It has been often noted by authors that early in the spring it is almost impossible to find larvæ of the codling moth under the rough bark and other exposed places in badly infested orchards. Instead of finding the cocoons with the larvæ inside, one will find empty cocoons with a hole through the bark of the tree, showing that the insect has fallen prey to woodpeckers. All places in which the larvæ might spin cocoons should be destroyed or rendered unsuitable, and the larvæ forced to spin cocoons in exposed places where the woodpeckers and other birds can get them.

The soil in these two orchards should receive about the same treatment, except that irrigation should be begun in the western orchard. They should both receive a very shallow cultivation for about one year, with a dressing of manure. The cultivation should be so shallow as not to injure any of the roots, which may be quite near the surface. The second year, red clover, cowpeas, or some other leguminous cover crop should be sown, and every third year this may be turned under, thus adding available plant food to the soil. When these methods are followed the recommendation given for an orchard in bearing should be adopted. At best the preventive measures can not control the insect in an orchard, but they are valuable adjuncts which render the measures more efficient.

REMEDIAL MEASURES.

Remedial measures against the codling moth are those measures from which little or no benefit is derived except in saving fruit from the ravages of the insect by killing it.

MEASURES OF LITTLE OR NO VALUE.

The codling moth seems to have been common in orchards for many centuries, but no one made any suggestions as to how its ravages might be checked. The first recommendations made were of no value, and it is interesting to note how these recommendations have recurred at various periods in popular writings. Many of these remedies, having little or no value, are taken up by companies, given all the benefit of modern advertising methods, and thoroughly distributed before the fruit growers become aware of their worthlessness. In order that the fruit grower may know what not to do as well as what he

should do, a number of the more prominent of these inefficient methods are briefly discussed.

It has often been recommended that moth balls be hung in the trees in order to keep the moths away. If there were any virtue in this remedy, so many of the moth balls would have to be hung on each tree, to do the work, that the expense would render it valueless.

Smudging the orchard, or burning ill-smelling compounds so that the fumes will pass through the trees, has been practiced to some extent. The theory is that the moths will be kept away by the fumes and go to other orchards to deposit their eggs. It is quite evident that as soon as these fumes are blown out of the orchard the moths will return if they have left, and in order to produce any results it will be necessary that the smudge be continued practically throughout the season.

Plugging trees with sulphur or other compounds and plugging the roots with calomel have been practiced to some extent, on the theory that the sulphur or calomel will be taken up by the sap, distributed through the tree, and prove distasteful or poisonous to the insect. Trustworthy scientific experiments have been carried on which show that it is absolutely impossible for the tree to take up any amount of these substances, and little or no effect upon the insects results.

The writer has found several orchards in which the trees were banded with tarred paper, the evident intention being to keep the larvæ from getting up into the trees. Knowing the habits of the insect when in its larval form, we can see that this method is ridiculous, and instead of being a detriment it is a positive aid to the insect; in many cases larvæ were found which had spun cocoons under the bands, which formed a place in which they were comparatively free from the attacks of their enemies.

There seems to be a popular idea among many farmers and fruit growers that all insects are attracted to light. Based upon this idea, there have been many recommendations to keep fires burning in the orchards, or to arrange some sort of a trap lantern by which the insects are to be attracted to the lights and fall into water on which is a film of kerosene and thus be killed. This scheme of trap lanterns was exploded many years ago, but it seems that at intervals somebody revives it, and its fallacy must be exposed afresh. By carefully experimenting with trap lanterns and determining the catch as accurately as possible it is found that the majority of the insects caught are either decidedly beneficial varieties, or are males, or females which have already deposited their eggs, and that but few injurious insects are caught, and none in any great number. Probably the most extensive experiments with trap lanterns were those conducted by Professor Slingerland. Among 13,000 insects he was not able to recognize a single codling moth. This is the usual result of all these experiments,

and we can say without any hesitancy whatever that the farmer who uses these trap lanterns or tries to experiment with them is simply wasting his time and money, as the method has been thoroughly proven ineffective.

It is also the practice to some extent to put cans or bottles containing molasses, cider, vinegar, or some other substance of similar nature in the orchard, and upon finding that insects are attracted by these compounds and killed, many fruit growers think this is a good remedy for the codling moth. The results of many careful experiments show that only incidental captures of the codling moth are made. With both these last two practices—that is, trap lanterns and baiting the moths—the greatest trouble has been that the fruit growers are not acquainted with the codling moth in its early stages. Any fruit grower can breed moths for himself, and by comparing his catch can very easily satisfy himself.

Many times fruit growers have tried spraying their orchards with ill-smelling compounds with but little success. These compounds are always more or less expensive and have never been so efficient as to justify their use.

Other fruit growers think that spraying the orchard with water frequently will give relief from the attacks of the codling moth. Undoubtedly if the trees were kept in a spray all the time, the fruit would be clear of the insect; but if this were done, the probabilities are that no fruit would set, and if any should set it would not ripen well, and the trees themselves would probably die. The expense of this operation would be many times greater than that of spraying.

It has been stated that electric lights repel the moth and that trees near electric lights in cities are often free from its work. The writer had an excellent opportunity to investigate this point, and found that an apple tree about 40 feet from an electric light was as badly infested as any other in that vicinity.

In order to do away with the labor entailed by using bands around the trees many kinds of traps have been invented. Riley, by careful experiments, showed that one of these traps would not catch as many larvæ as the bands; and other experiments have shown that these patent traps are never very efficient.

It was claimed for some time that the flowers of plants of the genus *Physianthus* might be efficient against this insect, since in order to reach the honey of the flower the proboscis would have to be passed through a narrow cleft, from which it could not be withdrawn, and the moth would therefore be held a prisoner until it died. It was proposed to train the vines around the trunks and branches of the trees, and, the moths being captured, the orchard would be protected. Conclusive evidence has been recorded which shows that these flowers have no attraction for the codling moth.

It has been suggested that the codling moth might be controlled by bacterial and fungous diseases. From the facts that the insect leads such a protected life and that fungi and bacteria have given so few positive results in this connection it is almost useless, with our present knowledge, to even theorize upon the value of these agencies.

In general it may be stated that entomologists have at all times tried experiments with these different plans and are unanimous in their conclusions. If anything new and efficient is ever perfected by which this insect may be more easily controlled, no doubt entomologists will be its first advocates.

MEASURES OF VALUE.

By taking into consideration all the habits and variations of habits of the codling moth in its different stages we find that, like other insects, there are certain stages in its life history in which it is more amenable to remedial measures than at others. We find that it can be best attacked in the larval stage, although some experiments indicate that something can be done when it is in the egg stage. Cook found that by spraying an apple tree weekly from May 15 until the end of June with a strong soap solution he succeeded in preventing the infestation of a single apple by the larvæ. In laboratory experiments with kerosene emulsion Card secured good results against the eggs. Gillette also obtained good results with kerosene emulsion. The results of these experiments have never been put to practical use for many reasons. The kerosene emulsion would probably be so strong, in order to have any effect on the egg, that it might injure the tree. The kerosene would evaporate quickly, and thus its effect would be for but a short time. The expensiveness of kerosene in the West, and the number of times the spraying would have to be made to be efficient, would prohibit the adoption of this method. The insect can be more easily attacked, at less expense and with greater effectiveness, in the larval stage.

MEASURES USED AGAINST THE LARVA.

The remedial measures used against the larva vary according to whether they are used after it has been hatched and before or while it is entering the apple or after it has completed its growth and left the fruit. The greater effectiveness is secured by the use of arsenical sprays before the larva has entered the fruit. The effectiveness of these arsenical sprays against the codling moth was discovered by accident in 1872. Le Baron recommended the spraying of trees with Paris green to check the ravages of the cankerworm, which recommendation was adopted in many orchards with great success. Professor Slingerland states that the credit of this discovery belongs to Mr. E. P. Haynes and Mr. J. S. Woodward, who found that spraying with

Paris green not only rid the orchard of cankerworms, but that the apples on the sprayed part were much less affected by the codling moth. It seems that other people used Paris green for cankerworms in Iowa, but there are no indications that they were alive to the fact that at the same time they were checking the codling moth. Prof. A. J. Cook, of Michigan, took up the idea and by a series of careful experiments clearly showed that the treatment was very effective against the codling moth. Forbes, Goff, and numerous others have at various times carried on spraying experiments with arsenicals, with results that show this to be the most effective and cheapest remedial measure that can be used.

SPRAYING.

Spraying with arsenicals may be defined as putting a coat of any arsenical poison on the foliage and fruit of a tree, so that when the insects eat the foliage or enter the apples they eat some of this poison in their first few meals and are killed. Since the beginning of the practice of spraying there have been many important improvements in both spraying machinery and spraying solutions, which have rendered the process much easier than when primitive methods were in vogue.

SPRAYING MACHINERY.

There are as many kinds of spraying machinery as there are conditions to be met in spraying operations. There are certain spraying outfits devised especially for orchard work, varying from the common bucket pump to rather complicated machinery driven by gasoline engines. For a small home orchard or for an orchard of a thousand trees or less the writer would advise the use of a hand-power outfit. The capacity and cost will depend primarily upon the size of the orchard, the size of the trees, and the rapidity with which it is desired to spray the orchard. There are many excellent types of spray pumps on the market, and no mistake can be made in selecting any of the outfits of the better manufacturers, but there are several points which should be insisted upon. The interior fittings of the pump should be of brass and should be arranged so that the inside of the cylinder can be easily reached in order that repairs may be made. The air chamber, which insures a steadier stream and acts as a reservoir of force, is almost a necessity. A pressure gauge upon this air chamber will be of great value, as it will aid the man who does the pumping to keep the pressure at about the same point. The pump may be mounted upon a barrel, which may be stood on end or put on the side, or it may be mounted on a tank or upon the wagon frame on which the tank is mounted. These tanks are preferably of wood, and should be of very strong construction and securely bolted together with iron rods. Screens should be used to strain out particles which would clog

the nozzles, and should be used both as the water is put into the tank and as it is pumped out. It is highly essential that some mechanical device be used to keep the liquid in agitation so that the coarser particles will not settle to the bottom of the tank and render the mixture of variable strength, especially if Paris green is used. The hose may be any of the types in use, and a hose extension of some light tube, covered preferably with bamboo, should be used in order that the tops of the tall trees may be easily reached. A stopcock at the junction of the hose and extension can be used to great advantage.

The nozzles most used in spraying orchards are of two types—those which throw a fan-shaped spray, which are used for long-range work, and those which throw a cone-shaped spray, which are used for close work. Several of these nozzles may be placed on one bamboo extension, and thus the amount of liquid thrown increased. Four lines of hose may run from one pump, but it is found that so large a number causes confusion and that more work can be done with two lines of hose. The usual number of nozzles upon each extension or line of hose is two. The nozzles can be set at an angle to the axis of extension, and then by turning the extension the stream can be variably directed. If the spraying outfit is small, consisting of a barrel with a pump, it can easily be hauled through the orchard on a sled; but if the outfit is larger it is usually drawn upon an ordinary wagon. Details of the mounting on the wagon and the position of the pump and tanks will depend a great deal upon the facilities which the grower has at hand. Many have the tanks and pumps mounted upon a frame, which they can put upon the wagons and remove when the spraying is completed. If it is desired to spray very tall trees, it has been found that spraying can be done more rapidly and thoroughly if there are high platforms built upon the wagons upon which the operators can stand (fig. 17). The capacity of these hand-power spraying outfits depends upon many factors, such as the number of men employed, size of pump, number of nozzles, capacity of tank, distance from water supply, and size of trees. It has been found that three men, using a 200-gallon tank and two lines of hose, each fitted with two nozzles, can spray about 250 average-sized trees per day. These hand-power spraying outfits can be purchased and put in working order for from $15 to $75. A pump, if used for arsenicals alone and given good care, should last for five or six years with but few repairs. But if the same pump is used for spraying with the lime, sulphur, and salt compound, and the compound allowed to corrode the pump, it will be necessary to purchase a new pump oftener. (See Pls. XI and XII.)

GASOLINE-POWER SPRAYING OUTFITS.

If an orchard consists of more than a thousand trees, it will be found expedient to use a gasoline-power spraying outfit. If the orchard

consists of five to ten thousand trees, it will be found that the expense per tree with this outfit is only about half of what it would be with hand-power sprayers.

Many dealers have placed spraying machines on the market in which the power is derived from gasoline engines. They consist largely of engines, pumps, and machinery for other uses, placed together for this purpose. While a majority of these are quite well adapted to the work of spraying, many improvements are possible which would

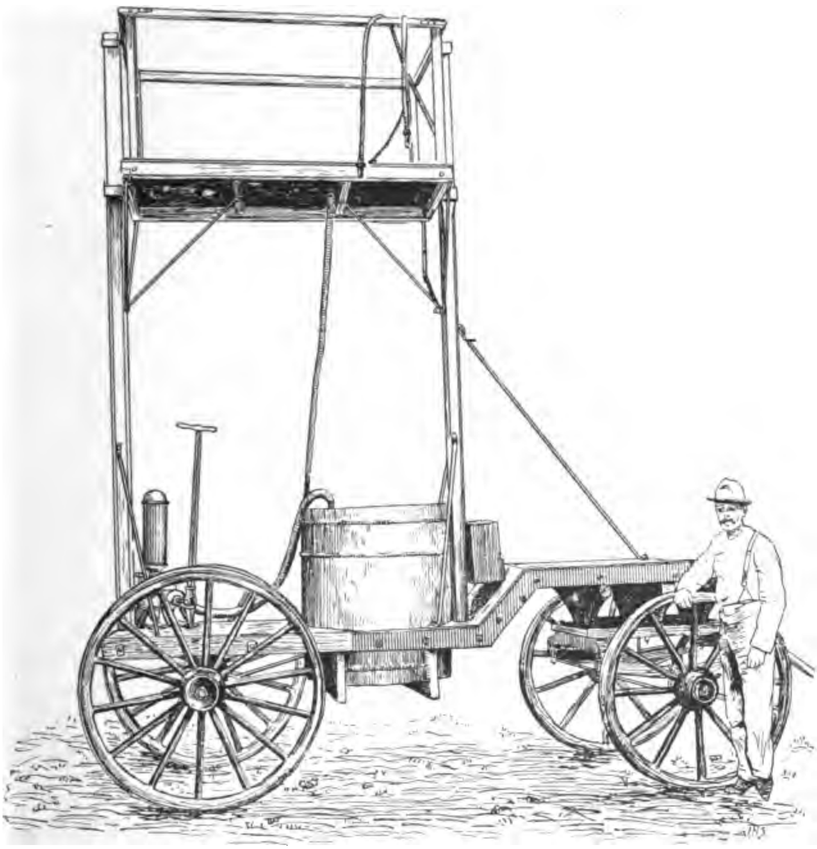


FIG. 17.—Spraying outfit for treating tall trees (after Gould).

increase efficiency without increasing cost. There are many makes of gasoline engines, most of which are well adapted to this work. The horsepower of the engines is usually too large. An outfit with which the writer is most familiar is run by a 1½-horsepower gasoline engine, and in ordinary spraying operations it was found that the engine was too powerful, as four out of nine possible explosions were all that was required to run the pumps and keep the pressure at 100 pounds. The engine for spraying purposes should be about 1 horsepower, which

may be more than is required at ordinary times, but occasions may arise when more power would be desired.

There are many methods by which gasoline is fed into the cylinders of these engines. The better engines have a pump by which the gasoline is forced into the cylinder. The ignition is accomplished by one of two methods—either by an ignition burner on the outside of the cylinder which communicates heat to a platinum point which explodes the gasoline vapor, or by an electric spark from an induction coil which is connected with numerous dry batteries. The cooling tank used with these engines for the purpose of keeping the cylinder moist and cool is usually from 12 to 14 inches in diameter. This size is intended for stationary engines, where the water can not be renewed frequently. In spraying, however, the water can be renewed every few hours if necessary; and therefore the tanks can be built as small as 6 inches in diameter, which will make a considerable reduction in the weight of the machinery.

Purchasers are always given full instructions in regard to the care and running of these engines, so that one with comparatively little mechanical ingenuity has very little trouble. The greatest source of difficulty is with the electric current. The insulations often become imperfect or the sparking points become dirty and fail to produce a spark. By carefully testing the current and keeping these points clean practically all of the trouble is avoided.

It is preferable to place the engine at the rear end of the frame and the pump as near the engine as possible. There are two types of spraying pumps which may be used for this purpose—the triplex pump, which consists of three vertical plungers, and the straight horizontal double-acting force pump. Either of these pumps will be found to answer to the conditions required for these outfits, but the horizontal pump is more commonly used. The pumps should be so manufactured that all of the parts are accessible and the brass lining easily removed. The working parts should be made of brass or bronze. A large air chamber is essential, as well as a pressure gauge. It is absolutely necessary that a relief valve be attached to the pump, so that when the stopcocks on the bamboo extension are closed the engine will not have to be stopped, but at a certain pressure the spraying liquid will be returned to the tank.

In sections of the country where irrigation is practiced it has been found that the most effective method of filling the tank is to have another pump which can be attached to the engine, by which water can be pumped from an irrigating ditch into the tank. This pump should belong to the type known as "low-down pumps," which deliver large quantities of water at low pressure. The suction hose should be 2 or 3 inches in diameter and the end which is put into the irrigating ditch should be w 'l screened. There is usually some

method by which this pump can be connected with the engine. It is unnecessary to disconnect the spraying pump from the engine, as the suction hose of the spray pump may be removed from the spraying tank. This filling pump and connections can be purchased for about $20, and the time and labor saved by its use will pay for it many times over during the season. This idea of having a filling pump attached to the spraying machine was originated and carried out successfully by Hon. Edgar Wilson, of Boise, Idaho.

As before stated in regard to hand-power outfits, it is found much more expedient to use only two lines of hose. The length of this hose will depend upon the method used in spraying the trees. Bamboo extensions and nozzles are the same as those used in power outfits. It is found that water from irrigating ditches contains a considerable amount of sand. The effect of the sand and the lime in the spraying solution is to cause the face of the nozzle to become badly worn, rendering it unfit for use in five or six days of continuous spraying. Letters have been written to the more important manufacturers calling their attention to the fact that if these faces were hardened or made of steel the nozzles would last much longer, and it may be that these firms will shortly put such improved nozzles on the market.

The tanks used in these spraying outfits may be made of wood or galvanized iron. The latter would be preferable on account of its lightness, but it would be disadvantageous because it would be somewhat difficult to thoroughly brace it. The tanks should not have a larger capacity than 150 gallons and should be placed on the front end of the frame. Screens should be placed over the end of the hose leading from the filling pump, as well as over the suction hose from the spraying pump.

The agitator which has given the best satisfaction in this connection is formed by two paddles set at an angle, mounted on a vertical shaft, and run by power derived from the gasoline engine by means of a belt and bevel gearing. This agitator keeps the spraying solution in violent agitation and renders it uniform.

The whole machine, engine, pumps, and tank should be mounted upon a rigid frame. On this frame there should be a platform at either side, with a railing, upon which the operators can stand. There should be supports for the bamboo extensions placed near the center of the outfit. (Pl. XI, fig. 2.) This frame can be mounted upon an ordinary wagon, but it is preferable to use a low wagon with steel wheels and tires not less than 6 inches in width, which will largely prevent the wheels from sinking into the soft earth. A team and two men are required to operate this outfit. Both of the men spray; one drives, and the other starts and stops the engine. This reduction of labor makes a material reduction in the cost of spraying.

Many tests have been made of these machines working under actual

conditions, and it is found that 700 trees (in the West, where they are considerably larger than trees of the same age in the East) can be easily sprayed in one day. Some fruit growers tell the writer that they have been able, when they found it necessary to work more rapidly, to spray 900 trees per day. By a series of observations it has been found that it takes from four to five minutes to fill the tank by means of the filling pump, and the same amount of liquid can be sprayed out in from thirty to forty minutes, upon from 60 to 80 trees, depending on their size, using about 2½ gallons per tree. In an irrigated orchard it is quite desirable that the ground be allowed to become dry before the spraying is begun, and thus avoid miring the machine in the soft earth, which will frequently occur in wet places in the orchard, especially when the tank is full.

The cost of these complete machines varies with the cost of the engine and pump and their fittings. They can be purchased for from about $260 to $500. The machine with which the writer is most familiar cost $320, which included a $40 wagon and filling pump and attachments at $20. With good care and proper repairs these machines can be made to last for several years. In a working day of ten hours it was found that a 1½-horsepower engine consumed about 1 gallon of gasoline. Although the initial expense of this outfit is greater than that of the hand-power outfit, it will be found to be much cheaper in the end, as the engine can be made to more than pay for itself by other uses when spraying is not in progress, such as running the cider press, feed cutter, and cream separator, sawing wood, turning the grindstone, and numerous other tasks about a farm for which power is desired. The machinery can also be removed from the wagon and stored in an outhouse and the wagon used for other purposes.

WATER SUPPLY.

The distance of the water supply from the orchard is one of the greatest factors in determining the rapidity with which spraying can be done. With the water supply some distance away much valuable time is lost in going to and fro to fill the tank. In the smaller orchards, where but little spraying is done, the usual custom is to drive the wagon to a ditch, pool, or well, where the water is transferred into the spraying tank with buckets. Many fruit growers have found it advantageous to draw their supply of water from an elevated tank into which water is pumped by a windmill or piped from some spring or stream. For irrigated orchards the water is usually taken direct from the irrigating ditches, sometimes from the main ditch and sometimes from the lateral ditches running through the orchard. By taking the water from these laterals in the orchard the routes of the spraying apparatus in operation can be largely determined, the foreman trying at all times to be near one of them when

the tank becomes empty. By means of the filling pump on the gasoline power outfits much valuable time can be saved in the operation of filling the tank, as compared with the method of having an extra wagon to haul water to the spraying outfit, sometimes employed. The routes followed by the spraying machine in the orchard depend upon many factors, such as source of water supply, position of hills and ridges, and direction of wind. Each orchard is a problem by itself, and experience will show which routes can be followed with the least loss of time.

APPLICATION OF SPRAY.

There are many methods of spraying the trees. In following the chosen route through the orchard some use four lines of hose, completely spraying four rows of trees at a time; but it has been found in actual practice that on account of the long hose and the great distances the men have to walk other methods are more advantageous. Many use two lines of hose, and men standing on the ground go completely around the trees, thus spraying two rows on all sides. Other fruit growers drive down one row and spray half of the tree on either side; coming back on the other side of the row they spray the other side and one-half of the next row. It has been clearly shown that this method gives the best results, both in the saving of time and in completely covering the trees. When the trees are tall it is quite necessary that the men ride upon an elevated platform, and it has also been found advantageous in using the gasoline-power outfit to have the men ride on the apparatus. In this way not only the men are saved unnecessary labor, but from their elevated position they can spray the trees more thoroughly. With the nozzles set at an angle on the bamboo extension, part of the tree can be sprayed as it is being approached. Then on stopping at the tree the whole side can be sprayed, and when leaving it the last part can be sprayed and spraying be begun on the next tree. It is almost impossible to spray while moving at right angles to a strong wind, and if such a wind is encountered it will be found desirable to have the wagon go either with or against it and take advantage of it by allowing it to blow the mist through the trees. Experience on the part of the operators will enable them to devise methods to reduce the time without impairing the effectiveness of the spraying.

The ideal to be attained in applying spray is to cover the tree with a thin coating of the spray solution, so that when the water dries it will leave a coating of poison on every portion of the foliage and fruit. When the spray is applied with but little force the stream does not break up into sufficiently fine globules, and when they strike the foliage they either cover only a small portion of it or run together into large drops and fall to the ground, leaving but little of the solution on the tree, and that little very much scattered. If, however, the spray

is applied with great force, the stream is broken up into a fine mist, which, if well directed, is evenly distributed over the foliage and fruit, and upon drying leaves a more or less uniform coat. If the nozzle is held close to the foliage, the force causes it to spread well, but the coating is not so uniform as that which is derived from the mist. In spraying one-half of a tree the mist drifts through the tree from the side which is being sprayed, and in that way the tree is well covered, having received practically two incomplete sprayings. If fruit is allowed to grow in clusters it is necessary to apply the spray with great force in order to secure good results.

MATERIALS FOR SPRAYING.

CONTACT INSECTICIDES.

Contact insecticides are those which kill the insects by touching them. Kerosene emulsion and solutions of whale-oil soap are the substances that have been most used for this purpose; but on account of the expense, the necessity of frequent application, and the fact that the insect can be more easily and effectively reached in other stages by other insecticides, these kinds of spraying solutions have been used but little against the insect.

ARSENICAL SPRAYS.

The arsenical sprays contain arsenic as their essential ingredient. Other chemicals are mixed with the arsenic for the purpose of preventing it from burning the foliage or are products incidental to the numerous compounds of arsenic which were used for other purposes than spraying. There are many spraying compounds of which arsenic is the base on the market, but there are many others which the fruit grower can make for himself by combining the necessary ingredients.

Paris green is probably the best known of these arsenicals. It has been used for many years with success, and is a definite chemical compound of arsenic, copper, and acetic acid. The composition is usually quite uniform, but many instances have been found in which it was adulterated or the percentage of soluble arsenic was dangerously high. As indicated by its name, it is a substance green in color. It is a rather coarse powder, which has the fault of settling rapidly in the spraying tank. It is quite necessary to use lime with Paris green in order to counteract the burning effects of the free arsenic. Paris green is comparatively expensive; in the East it costs about 20 cents a pound and in the West 25 cents.

Paris green may be prepared for spraying as follows:

Paris green	pound	1
Lime	pounds	1 to 2
Water	gallons	100 to 250

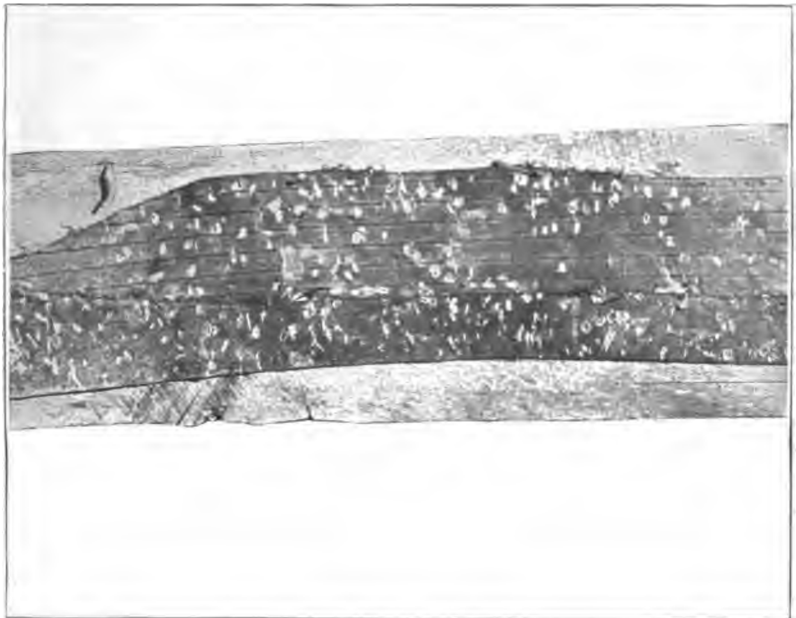


FIG. 1.—BAND ON WHICH THE REMAINS OF 330 COCOONS WERE COUNTED.

FIG. 2.—PUPA IN COCOON ON UNDERSIDE OF A LOOSE PIECE OF BARK.

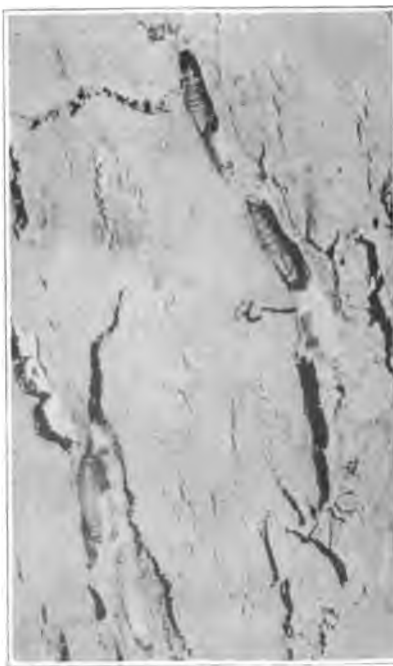


FIG. 3.—LARVA AND PUPÆ IN CRACKS IN BARK, FROM WHICH ROUGH BARK HAS BEEN REMOVED.

FIG. 1.—GASOLINE-POWER SPRAYER, SHOWING THE ENGINE AND SPRAY PUMP.

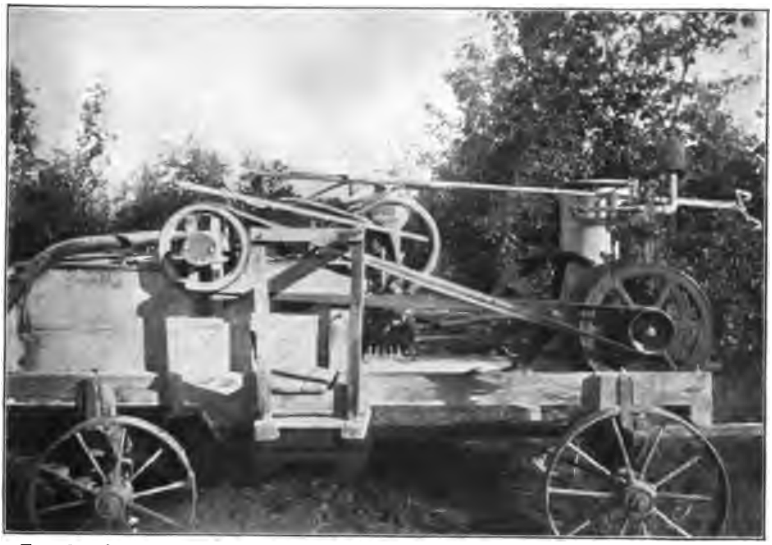


FIG. 2.—GASOLINE-POWER SPRAYER AS IT WAS IMPROVED DURING THE SEASON.

FIG. 3.—SAME SPRAYER AS IN FIG. 1, BUT SEEN FROM THE OTHER SIDE, SHOWING FILLING PUMP AND ATTACHMENTS.

GASOLINE-POWER SPRAYING MACHINES.

FIG. 1.—GASOLINE-POWER OUTFIT IN THE ORCHARD.

FIG. 2.—FILLING TANK BY MEANS OF THE FILLING PUMP FROM AN IRRIGATION DITCH.

FIG. 3.—HAND-POWER SPRAYING OUTFIT, IN WHICH THE PUMP IS MOUNTED UPON A BARREL ON AN ORDINARY WAGON.

SPRAYING OUTFITS IN USE.

The lime should be fresh and slaked in small quantities as needed. By mixing a small quantity of water with the Paris green until a paste is formed it is much more easily distributed in the water. The lime may be added to the water in the proper quantity.

A good average strength of this solution is 1 pound of Paris green to 150 gallons of water; but for trees with delicate foliage, such as peach, it is advisable to use a much weaker solution. Many fruit growers are using Paris green of the strength of 1 pound to 100 gallons, with the addition of lime upon apple trees, without burning the foliage.

Scheele's green is a similar preparation to Paris green, but differs from it in lacking the acetic acid. It is a finer powder than Paris green, is much more easily kept in suspension, and the cost is only about half that of Paris green. There is but little of this insecticide manufactured and placed upon the market.

London purple is a waste product in the manufacture of aniline dyes. It contains a number of substances, of which the principal ones are arsenic and lime. It is quite variable in composition, and is generally considered as being not so effective as some of the other arsenicals. For spraying it is now being replaced by the other poisons.

Both Scheele's green and London purple are prepared for use in spraying similarly to Paris green.

WHITE ARSENIC COMPOUNDS.

If white arsenic is used alone in spraying, it will seriously injure the foliage of the trees by burning, but when combined with other chemicals which prevent this burning, it forms the base of our most effective sprays, any of which can be easily prepared by the fruit grower.

Arsenite of lime.

White arsenic	pound..	1
Lime	pounds..	2
Water	gallon..	1

The white arsenic and the lime are boiled together for not less than half an hour in the required amount of water, as it is very difficult to make the lime and arsenic combine. After the combination is complete enough water is poured in to replace that lost by evaporation. This solution may be kept as stock, and 1 pint of it used to every 40 or 50 gallons of water. It is advisable to add more lime to this spraying solution in order that all danger of burning may be avoided. Although this solution is by far the cheapest spraying material, there is much danger of poor combination of the arsenic and lime, leaving free arsenic, which will injure the foliage. In order that the lime may more thoroughly combine with the arsenic, soda has been used to facilitate the combination.

Arsenite of lime with soda.

White arsenic	pound	1
Sal soda (crystal)	pounds	4
Water	gallon	1

The ingredients are boiled in the required amount of water until dissolved, which will take place in a comparatively few minutes, after which the water lost by evaporation is replaced. To every 40 or 50 gallons of water a pint of this stock solution and from 2 to 4 pounds of fresh slaked lime are added. The chemical compound derived from the combination of the sal soda and the white arsenic is arsenite of soda. In the presence of lime this breaks down and arsenite of lime is formed. It requires 4.4 pounds of crystal sal soda or 1.6 pounds of dry sal soda to combine with 1 pound of arsenic and 2 pounds of freshly slaked lime to combine with 1 pound of arsenic to form arsenite of lime. It is always desirable to have an excess of lime present, in order to prevent all danger of burning; furthermore, this excess is a convenience to the fruit growers, because they can see by the distribution and amount of lime on the foliage how well the spraying has been done. This formula, which is the Kedzie formula, with a very few minor changes, has been used in many different sections of the country with unvarying success. In all of the practical tests under the advice of the writer this solution is used, and is found to be not only as efficient as other solutions, but far cheaper.

Arsenate of lead.

Arsenate of soda	ounces	10
Acetate of lead	do	24
Water	gallons	150 to 200

The arsenate of soda and acetate of lead should be dissolved separately and then poured into a tank containing the required amount of water. These chemicals unite readily, forming a white flocculent precipitate of lead arsenate, which is easily kept in suspension, and can be used in excessive strengths on delicate plants without the addition of lime. When sprayed upon the foliage it forms a filmy, adhering coat, which is but little affected by ordinary rains. There are several good preparations of lead arsenate upon the market. Some of these are prepared in a wet state, others in a dry or powdered form. The moist preparations are much preferable, because the dry powder does not give such a good coat of poison upon the foliage. This poison has given excellent results in use against the codling moth, but on account of its expense it is comparatively little used.

If it is desired to use Bordeaux mixture with any of these solutions the arsenicals are added to the Bordeaux mixture in the same proportions as they would be to a similar quantity of water. At all times the greatest care should be taken to prevent accidental poisoning with

these compounds.[a] The fact should be firmly impressed upon all those who have anything to do with these solutions that they are of the most poisonous nature. All packages, boxes, or bottles containing the materials should be plainly labeled and kept in secure places which can be locked. The utensils in which the mixtures are prepared should be thoroughly cleansed or kept in some secure place, so that no mistake can occur in using them for other purposes.

COST OF SPRAYING.

The cost of spraying is so small when compared with the benefits to be obtained that we can say it is the very best investment the grower can make. As with other farming operations, the first year will be more expensive than succeeding years, as by experience the fruit grower will be able to reduce expense considerably without impairing efficiency. It is a very difficult task to estimate the cost of spraying, for many factors enter into the problem. The initial cost of the outfit varies from $15 to $75 for hand-power outfits and from $260 to $275 for gasoline outfits. These outfits can be used for many years, and the parts of the gasoline outfit can be used for other purposes. The cost for spraying material amounts to little.

The cost of the different spraying materials will vary with the different sections of the country, according to the freight rates and the quantities purchased by fruit growers. Where a large amount of

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[a] Although no accidents are known to have occurred from the use of arsenicals in spraying, it is well to know what to do in case of accidental poisoning. If evil effects are noted in the case of persons who constantly handle these poisons, a physician should be consulted. If by any mistake or carelessness a small quantity is swallowed, an antidote should be employed without delay. The following extract in regard to antidotes for arsenic poisoning is taken from Poisons: Their Effect and Detection, by A. W. Blyth:

"In any case where there is opportunity for immediate treatment, ferric hydrate should be administered as an antidote. This converts the soluble arsenic acid into the insoluble ferric arsenate, the ferric oxid being reduced to ferrous oxid. It is necessary to use ferric hydrate recently prepared, for if dried it changes into an oxyhydrate, or even if kept under water the same change occurs, so that after four months the power of the moist mass is reduced to one-half and after five months to one-fourth. When once the poison has been removed from the stomach by absorption into the tissues the administration of the hydrate is absolutely useless.

"Ferric hydrate is prepared by adding strong ammonia to the solution or tincture of ferric chlorid found in every chemist's shop, care being taken to add no excess of caustic ammonia."

Lime water may also be used as an antidote, but it is not so effective as ferric hydrate. It is understood that after the antidote some emetic, such as mustard or warm water, should be administered immediately. Persons who use great quantities of arsenites in spraying, and who are some distance from drug stores, are advised to keep a small bottle of each of the chemicals named to use in making the ferric hydrate. In preparing ferric hydrate continue to add the ammonia until, after being well shaken, a faint odor of ammonia can be observed.

arsenites is used it is advised that they be purchased in 100-pound lots, using 600 gallons of spraying solution as a basis. Taking the prices of these different compounds as they are in the Far West, the following estimates are made:

Paris green:	
Paris green, 4 pounds, at 25 cents	$1.00
Lime, 8 pounds	.04
Total	1.04
Scheele's green:	
Scheele's green, 4 pounds, at 12½ cents	.50
Lime, 8 pounds	.04
Total	.54
Lime arsenite:	
White arsenic, 1½ pounds, at 10 cents	.15
Lime, 3 pounds	.015
Additional lime, 12 pounds	.06
Total	.225
Lime arsenite with soda:	
White arsenic, 1½ pounds, at 10 cents	.15
Salsoda, 6 pounds, at 1½ cents	.09
Additional lime, 6 pounds	.03
Total	.27
Lead arsenate:	
Arsenate of soda, 2½ pounds, at 10 cents	.25
Acetate of lead, 6 pounds, at 12 cents	.72
Total	.97
Prepared lead arsenate, 36 pounds, at 20 cents	7.20

From the foregoing quotations, any fruit grower can estimate the expense of spraying by changing the prices to those prevailing in his vicinity. The prices of these chemicals, excepting the lime and sal soda, are from about 2 to 5 cents per pound more in the West than in the East. The labor of preparing, which is but little, is another factor which must be included. In the preparation of arsenicals for a home orchard or a small commercial orchard it may be advisable for the fruit grower to purchase the more easily prepared compounds, such as Paris green or prepared lead arsenate, as this does away with much trouble and loss of time in preparing the solution.

Labor is the principal element of cost in actual spraying operations. The cost of one spraying for a thousand 8-year-old trees in the far West, using 2½ gallons of lime arsenite and soda compound per tree, is estimated as follows:

Hand-power outfit:

Man and team 4 days, at $3.50	$14.00
Two men 4 days, at $1.50 each	12.00
Materials	1.12
Total	27.12

Gasoline-power outfit:

Man and team 1½ days, at $3.50	5.25
One man 1½ days, at $1.50	2.25
Materials	1.12
Gasoline, 1½ gallons	.55
Total	9.17

The above estimates are taken from actual conditions in the field, and the prices of material and labor are based upon current rates in the far West, where they are considerably less than in the East. It is assumed that the men and teams were employed at the local rates; but as men and teams are already employed upon fruit farms, the actual expense of these spraying operations is much smaller. According to these estimates one spraying would cost 2.7 cents per tree if a hand-power outfit is used, or 0.9 cents per tree if a gasoline-power outfit is used. The additional cost to the fruit grower would be much less than this, and in some cases would probably not amount to more than 1 cent per tree with the hand-power outfit, or one-half cent per tree with the gasoline outfit.

TIME AND FREQUENCY OF APPLICATION OF SPRAY.

The time of application of the spray is one of the most important considerations in the work. It has been found that in many sections of the country fruit growers have sprayed without any definite knowledge as to when the spray would be effective, and many times it was not at all so, the effectiveness that it had depending more upon chance than anything else. Other growers follow the empirical rule of spraying once every two weeks after the blossoms have fallen. If this rule is followed no doubt many of the sprayings during the season have little or no effect upon the codling moth. It can be readily seen that to be effective the poison must be placed upon the trees so that when the larvæ are hatching they will get some of the poison; but if they are already inside the apples or in their cocoons they suffer very little from the spraying. Hence we find that where there are but two generations of the insect there are only two periods in the season when a large proportion can be affected by the poison, and these are the proper times for spraying. The work done at these two periods may be termed the early and the late sprayings, the early spraying being directed against the first generation of the codling moth.

Two sprayings at the early period are advised, one a few days after the blossoms have fallen and before the calyx closes, and the other

about two weeks later, when the majority of the larvæ are entering the fruit. There has been much discussion recently in regard to dispensing with the spraying immediately after the blossoms have fallen. It has been found that the larvæ enter the fruit from one to two months after the blossoms have fallen. In cases of bad infestation, where preventive measures have been neglected, or there is an abundance of the insect, it might be well to make three sprayings while the second generation is entering the fruit. This period varies with the locality and with the seasons in the same locality; but there are a few methods by which the time can be approximated with sufficient accuracy, and in view of the fact that the time is variable the writer does not wish to recommend that the spraying be dispensed with until each locality is studied. Spraying may be begun immediately after the first new entrance holes of the second generation are found, or about twenty days after the date the maximum of the first-generation larvæ are found under the bands ready to spin their cocoons. The larvæ of the second generation in southern Idaho usually begin to enter the fruit the last week in July, but the majority enter in August, and but few in September. The number of sprayings to be made against this generation depends entirely upon the success achieved against the first generation. It has been found quite definitely that the injury due to the second generation is much greater than that from the first generation; and if the injury due to the first generation is from 2 to 5 per cent the writer advises a third spraying for the second generation; but if the injury has been only 1 per cent or less, two sprayings will be found sufficient. The quantity of lime used in these late sprayings should be reduced to a minimum, as lime on the fruit depreciates its market value.

Light showers wash but little of the spray from the tree; but if there is a heavy shower or continued rain, a large amount will be removed, and it will be necessary to repeat the sprayings as soon as possible. Lead arsenate is less affected by rain than the other spraying compounds.

HOW THE POISON KILLS THE INSECTS.

Though Paris green has been used for spraying purposes for many years with success against the codling moth, it is only recently that any serious effort has been made to ascertain how the poison is obtained by the larvæ. Slingerland was the first to answer this question with any degree of accuracy. According to him the spray lodges in the saucer-like calyx when the young fruit is erect after the blossoms have fallen, and upon the segments or leaves of the calyx closing the poison is held there for some time. As about 80 per cent of the larvæ of the first generation enter the fruit through the calyx, it is easily seen how the majority of them would obtain some poison.

Calyces were analyzed and the poison found in them, showing that the closing of the lobes incloses some poison at least two weeks after the spraying has been done. The writer is unable to find any published record of any larvæ having been found in a calyx, which were killed or supposed to have been killed by the poison. The evidence which goes to show that they are killed is all indirect. In Idaho in 1902 the writer gave special attention to this most difficult point. By examining the apples immediately after the blossom had fallen it was found that the calyx proper consisted of two parts; first, the calyx tube, which we may say is on the interior of the apple, and then the lobes or bases of the lobes which support the stamens. The stamens stand close together and form a sort of roof over the calyx tube. The writer has many times cut open this calyx tube after spraying has been done, and was unable at any time to distinguish any particles of spray inside the tube. The writer is also unable to give any definite figures as to what percentage of the larvæ enter the apple by way of the calyx tube, but it is possible that it is large. The difference in percentages of larvæ which have entered the calyx on sprayed or unsprayed trees should indicate the efficiency of the spray. Table III gives 82 per cent as entering the calyx on sprayed trees and 80 per cent on unsprayed trees. There was lack of data in regard to the sprayed trees, which was not discovered until it was too late to obtain a new series. Cordley finds that the larvæ do not enter the fruit until two months after the petals have fallen, and on that account does not recommend the spraying immediately after the blossoms have fallen.

How the larvæ of the second generation are killed is a question still in a somewhat chaotic state. It is generally believed that the larvæ get the poison when they enter the fruit, but the observations of many investigators, including the writer, show that when the larvæ are entering they eat little or none of the fruit. In both sprayed and unsprayed orchards it is quite common to find places where they have entered the fruit and have died shortly after entering. Countings on 426 new entrance holes in sprayed trees showed that there was an average of 40 per cent of the holes in which the larvæ had died, and in two counts this percentage went as high as 70. Other countings on unsprayed trees gave, out of 606 new entrances, 11 per cent in which the larvæ had died. As there is no way of knowing accurately how many of these holes were caused by larvæ which entered the fruits where two apples touched, these data can not be relied upon, but the writer believes that during the period in which the entrance holes were made at least 10 or 15 per cent of the larvæ succumbed to the spray. Twice larvæ were found dead before they had entered the fruit. Many times early in the season holes were found, the making

of which would employ the larvæ for several days. In these cases it is questionable whether or not the spray killed the insects.

In regard to the entrance of the second generation, the larvæ may get some of the poison when their jaws are slipping on the fruit in the attempt to make an entrance, but at best the percentage probably killed in entering the fruit can in no way account for the general efficiency of spraying. Considering the egg-laying habits and the leaf-feeding habits of the larvæ of both generations, the writer is strongly of the opinion that by far the larger number of the larvæ killed by spray are killed through eating or nibbling the poisoned leaves before they find fruits. It is to be hoped that future years will develop more definite data on this subject.

THE BANDING SYSTEM.

As before indicated, upon leaving the fruit the larva seeks some place in the crevices or loose bark in which to spin its cocoon. This fact was known as early as 1746, but it was not until 1840 that Burrelle, of Massachusetts, discovered that by winding something around the tree or placing cloth in a crotch many larvæ would be induced to collect there and could then be destroyed. He recommended destroying them in a hot oven. The banding system was further studied and elaborated by Dr. Trimble, who recommended hay ropes for bands. Very soon this became the most successful method used, and up to about 1880, by its use many fruit growers were able to save considerably more of their fruit than before. Many other observers have made studies of these bands and proved what was best in the way of material and the manner and time of application, until now it is one of the very best adjunct methods in the control of the codling moth. Generally speaking, the system of banding is simply furnishing the larva a good place in which to spin its cocoon and killing it after it has done so. (See Pl. X.)

The materials used for these bands may be designated as temporary and permanent. The temporary bands are composed of hay, paper, or any other cheap material, and, after the larvæ have entered the bands, are burned with the contained larvæ. Permanent bands are usually of cloth; these, after the larvæ are killed, are replaced on the tree. The materials for these bands are various, and it has been found that the most efficient is some dark, heavy material. Bands of thin muslin are quite inefficient. Professor Aldrich recommends brown canton flannel. In orchard practice it is found that fruit growers use almost any material, such as old clothes, burlap, and canvas.

One of the most essential features of the banding system is to render all other places on the tree unsuitable for the spinning of the cocoon, thus leaving the band the only alternative. Cracks in the tree should be filled, the rough bark scraped away, and all other obstacles removed.

The band should consist of a piece of cloth long enough to go around the tree more than once, and from 10 to 14 inches in width. This piece of cloth is folded once lengthwise and placed around the tree. There are many devices for holding the bands in place upon the tree. The one which gives the most satisfaction, and allows the band to be removed and replaced most readily, consists of driving a small nail through the ends of the band after wrapping it around the tree, and then nipping off the head of the nail in such a manner as to leave a sharp point. Subsequent removal of the band is accomplished by simply

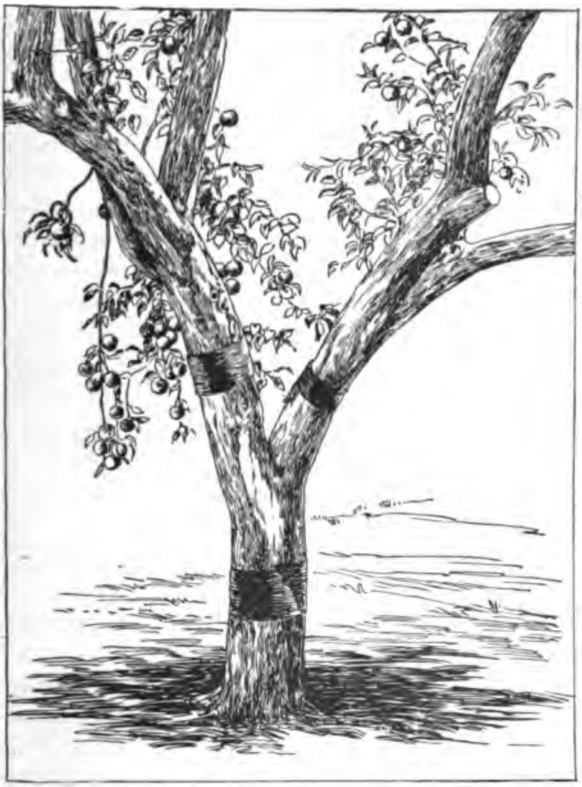

Fig. 18.—Large apple tree properly banded for the codling moth (original).

Fig. 19.—Apple tree banded, showing bands both above and below a hole in the trunk (original).

pulling the ends off the nail, and replacement by pushing them down again over it. Ordinarily one band to the tree is sufficient in general orchard practice, but in cases where the trees are large and have a number of large branches, it is advisable to put one band around the trunk and one around each of the larger limbs. (Fig. 18.) Where there are holes in the trees which can not be rendered unsuitable for the spinning of the cocoons, it is the best to put bands both above and below them. (Fig. 19.)

Many writers have experimented upon the effect of several bands upon the tree. LeBaron gives the following table:

TABLE VIII.—*Number of larvæ caught under bands.*

	Date of examination.				
	July 28.	Aug. 11.	Aug. 25.	Sept. 9.	Sept. 23.
Bands on limbs	43	31	7	9	4
Middle bands	83	13	15	39	22
Lowest bands	94	21	24	33	28

On a single tree, from July 4 to July 23, the same writer found 110 larvæ under the top band and 150 under the lower band.

The author states that the windfalls in every case were left as they fell. In the season of the year when a large number of the wormy apples were on the ground the lower band caught most of the larvæ, while during July, when the windfalls caused by the first generation had hardly begun to fall, the larger number of larvæ were caught bv the upper band.

Professor Aldrich experimented upon one large tree and five bands. The table made from these experiments is here given.

TABLE IX.—*Professor Aldrich's record of bands on one tree.*

	July—				August—				September—				October—			Total.
	7.	15.	21.	30.	6.	12.	18.	26.	4.	10.	17.	25.	1.	8.	15.	
Top	2	27	32	11	20	7	8	4	4	6	....	2	0	20	13	156
Second	0	4	9	12	1	6	13	3	1	3	....	7	8	9	4	80
Third	1	4	5	12	14	6	0	6	2	3	....	3	13	11	6	86
Fourth	1	4	11	11	11	3	4	2	1	2	....	4	7	8	6	75
Bottom	0	3	7	18	17	1	7	8	4	3	....	8	9	7	3	97
Total	4	42	64	64	63	23	32	23	12	17	....	24	37	55	34	494

Out of a total of 494 larvæ about 30 per cent were caught on the upper band, and the lower band caught more than any of the intermediate ones. The experiment also shows that in seeking a place for their cocoons the larvæ will cross several bands, and as there is no way by which those going up the tree and those going down can be separated, no exact percentages of such can be given.

Wickson found by carefully conducted experiments that while 2,704 apples and pears were counted from which larvæ had escaped, there were only 1,188 under the bands, or 44 per cent. The remaining 56 per cent either found other places in which to spin their cocoons or were destroyed by their enemies. The percentage of larvæ caught upon a tree will depend entirely on the condition of the tree. If the tree is free from cracks, holes, and rough bark, more larvæ will be caught; while if there are other places in which they can spin, fewer of them will go under the bands.

It has been fully demonstrated that in badly infested orchards of the West only a comparatively small percentage of the fruit can be saved by bands alone.

After the larvæ have collected under the bands they must be killed or the bands will become a positive aid to the insect. The usual method of examining the bands is as follows: One end is removed from the nail and rolled back upon itself around the tree. As the cocoons, larvæ, and pupæ are exposed they are cut in two with a sharp knife or crushed. Many methods have been devised by which these bands can be collected in wagons and brought to a central place, where they are put in hot water, run through wringers, or some other device used to kill the larvæ; but in view of the fact that many of the worms will crawl out in transit, and comparatively few of them remain attached to the bands, these methods must give way to the one described. Another important point is the length of time which should intervene between the examination of bands and the killing of the larvæ. This time depends entirely upon the length of time which it takes the larva to emerge as a moth after having left the fruit. In the warmer sections of the West 6 or 7 days has been recommended. By extensive experiments carried on by Professor Gillette and the writer it was found that practically none of the moths issue until after 11 days from the time they entered the bands. The data upon which the recommendation of 6 or 7 days was based have in some cases been found to be quite inaccurate. When the trees were examined not all of the larvæ were killed, and the second week afterwards some of them were found to have emerged, and from this the conclusion was reached that some of them went through the cocoon stage in 6 or 7 days. The experiments by the writer and Professor Gillette have been found in practice to allow a small number of moths to escape. A person examining bands frequently can easily tell whether the time is too short or too long. If the time is too long, many empty pupa cases will be found projecting from the band, whereas if the time is too short most of the insects will be found in the larval stage, not having had time to transform to pupæ.

EXPENSE OF BANDING.

When compared with the cost of spraying, banding is comparatively expensive. One man can examine the bands and kill the larvæ on about 300 trees in one day. Counting his wages at $1.50 per day, we find that it costs about $5 a thousand trees for one examination, which is about half the cost of one spraying. The bands should be placed upon the trees in the spring at about the time the earliest larvæ of the first generation begin to leave the fruit. This time is usually about two weeks after the first wormy fruits have been noted, and in southern Idaho is about June 15. It is always well to apply the bands a week or so earlier than there is any necessity for. The bands should be examined every ten days and the larvæ which have collected in them killed. This makes about ten or eleven examinations of the bands in the course of the season. Examination after the first week

in September is unnecessary in southern Idaho and practically all of the Pacific northwest, as very few moths emerge after this time. After the fruit has been picked and carried off, the bands should be removed, all the larvæ in them or on the trees killed, and the bands stored, because if they are left in the orchard they will soon rot.

WHEN BANDS MAY BE USED.

Bands may be used to great advantage in an orchard bearing its first crop, which is but little infested. Many growers whose orchards are more or less isolated and but little infested use the banding system as a means of control. One of these is Mr. I. B. Perrine, of Blue Lake, Idaho, who has had great success in keeping the injury in the worst infested section of his orchard down to less than 3 per cent.

The most important use of the bands is as an adjunct to spraying in a badly infested orchard when it is desired to bring the codling moth under control in that orchard, or in general practice when the trees are large and the spraying can not be well done on account of either the inefficiency of the spraying machine or the height of the trees. However, the writer, by many extensive experiments, has clearly demonstrated that when four or five sprayings are made with the gasoline power outfit, and the spraying solution is thoroughly applied at the right time, banding is unnecessary. In orchards where spraying is the only remedial measure used it is advisable to keep bands on four or five normal trees, killing the larvæ at stated intervals and recording the results, so that the band record may act as an indicator for the conditions in the orchard.

PRACTICAL TESTS.

The season's work in 1900 may be summed up in saying that the work accomplished simply outlined the problem of the codling moth in the Pacific northwest. In 1901 the apple crop was so unusually small that all practical tests which had been begun were abandoned, and the time devoted to a study of the life history of the insect and planning a campaign for the following year. It was decided to give the recommendations of previous years a thorough practical test under actual field conditions from the fruit grower's standpoint. Some difficulty was experienced in obtaining orchards in which to work. Keeping in view the idea that the codling moth is the greatest injurious factor in the commercial orchard, a large amount of work was done in such orchards, the principal part in the orchard of the Wilson Fruit Company, near Boise, Idaho, through the kindness of Hon. Edgar Wilson, and in that of Mr. Fremont Wood. Mr. McPherson's orchard and that of Mr. David Geckler were visited frequently and observations made. There were many orchards in various localities in which no measures were used against the codling moth, and these were used as checks upon the sprayed orchards. In Idaho the injury

by the codling moth in 1902 was quite variable, as there had been but a scattering fruit crop the year before, and consequently a lack of insects in some localities.

The orchard of the Wilson Fruit Company, which is a type of the very best commercial orchards in Idaho, was planted in 1894 by Hon. Edgar Wilson, and was sold by him to the company which is the present owner in the early spring of 1902. Mr. Wilson acted as manager for the orchard company for the season, aided by Mr. W. F. Cash. This orchard consists of 650 Ben Davis trees, 500 Jonathan, 750 Rome Beauty, 141 Northern Spy, and 800 trees which were planted as Wolf River, but were subsequently budded to Jonathan, and have not yet come to bearing. There are three short rows of Pewaukee, and a few trees of other varieties scattered throughout the orchard.

The house in which the apples were packed and the culls stored in the fall of 1901 is about 200 feet from the orchard and has always been a source of infection for it. (Pl. IV, figs. 2 and 3.) Early in the season of 1902 Mr. Wilson purchased a gasoline-power spray outfit and prepared to give the orchard a thorough spraying. The improvements made by Mr. Wilson and Mr. Cash have rendered this machine one of the most efficient for this purpose. A single spraying was accomplished in about four days, using lime arsenite with soda exclusively as a spraying solution. About 2,000 very heavily loaded trees were in bearing. The conditions of the previous season were such that there was an abundant supply of insects present in 1902, except in the Rome Beauty section. The writer estimated in 1901 that from 40 to 60 per cent of the fruit in the Jonathan and Ben Davis sections was infested, no late spraying having been made; and the small amount of fruit in the Rome Beauty section was all infested.

No bands were used, except upon the trees left unsprayed and a very few near the apple house. The blossoms of the Jonathan and Ben Davis were fully open about May 10, and had dropped about May 20. The Rome Beauty blooms through a longer period of time, and some blossoms were observed as late as June 1. Spraying should have begun about May 19, but on account of continued rains it was delayed until the 23d, at which time the orchard was given a thorough spraying. After two weeks the orchard was again sprayed, at about the time the first larvæ were beginning to enter the fruit. By the 1st of July about all of the larvæ of the first generation had entered the fruit. Countings on the Ben Davis and the Jonathan section gave an average of a little less than 1 per cent infested, while the Pewaukee trees, which were unsprayed, had from 20 to 26 per cent infested. The Jonathan tree nearest the apple house had about 5 per cent wormy, but this percentage decreased rapidly in the surrounding trees. Other orchards in the same condition showed from 10 to 50 per cent wormy; while orchards in which no remedial measures had been applied, and in which no insects were left over from the year before, showed a very

small percentage wormy. In the last week of July, at about the time the second generation was beginning to enter the fruit, a third spraying was made; and the fourth spraying was made about August 8, at which time a demonstration was made to visiting fruit growers. About ten days after the spraying a dashing rain washed off a considerable amount of the spray. Mr. Wilson and Mr. Cash did not think it advisable to make another spray, in view of the fact that the results already secured were so satisfactory that they thought it unnecessary. There is no doubt in the mind of the writer that if this spraying had been made the results would have been better.

Harvesting began about the second week in October, at which time the final results were obtained. Many trees were selected early in the season and the wormy fruit upon them counted; but as the season progressed the number was reduced on account of the lack of time to make the proper countings. The following table is compiled from the results upon six average-sized Ben Davis trees which were situated about the center of the Ben Davis section. At all times the greatest care was exercised in making these countings as accurate as possible, every one of the apples being counted and no estimates made.

TABLE X.—*Infested and non-infested apples on six sprayed trees.*

Number of trees.	Date.	Apples on tree.			Fallen apples.				Total apples.	Total apples infested.	Total per cent infested.
		Infested.	Free.	Total.	Infested.	Free.	Total.	Per cent infested.			
1	July 16	15			10	330	340	2			
	Aug. 22	2			29	83	112	25			
	Sept. 4	12									
	Nov. —	153									
	Total	182	1,364	1,517	39	413	452		1,998	221	11
2	July 16	3			21	410	431	4.8			
	Aug. 22	6			45	123	168	26			
	Sept. 4	19									
	Nov. —	143									
	Total	171	1,107	1,150	66	533	599		1,777	237	13
3	July 16	4			26	37	63	41			
	Aug. 22	10			10	16	26	38			
	Sept. 4	11			1	7	8	12			
	Nov. —	167									
	Total	192	977	1,144	37	60	97		1,241	229	11
4	July 16	12									
	Aug. 22	0			32	133	165	19			
	Sept. 4	4			4	10	14	28			
	Nov. —	129									
	Total	145	1,430	1,559	36	143	179		1,433	181	10
5	July 16	4			22	65	87	25			
	Aug. 22				17	46	63	26			
	Sept. 4	12			0	23	23	0			
	Nov. —	152			30	63	93				
	Total	168	1,228	1,396	69	197	266		1,662	237	13
6	Aug. 13	19			19	82	101				
	Sept. 4	7			0	16	16				
	Nov. —	174			50	141	191				
	Total	200	1,210	1,384	69		308		1,892	269	14

The large amount of free fallen apples on trees No. 1 and No. 2 are due to the apples picked off in the process of thinning. The average total per cent infested throughout the season for these trees was 13.

The greatest difficulty was met with in obtaining any reliable estimate upon the general results from the orchard, for the reason that the larger percentage of the seconds and culls were graded as such because they were small or uncolored. The Ben Davis section produced 1,944 boxes of strictly first-class fruit, and the writer estimates that this was only about one-third of the total produced. In one section of the orchard there were trees in which the loss was fully 25 per cent at harvesting time, but there were many others in which the loss was not over 5 per cent. The writer estimates that at picking time about 10 per cent of the fruit in this section of the orchard was infested. In the Jonathan section 2,030 boxes of first-class fruit were packed, and the culls were estimated at 146 boxes. By numerous counts it was found that only about half of these were infested, which gives a total of 73 boxes of infested fruit. As a general result, about 3 per cent of the apples were found infested, and the total percentage for this section of the orchard was probably about 5. It was found that the tree nearest to the packing house was about 50 per cent wormy, but the percentage diminished rapidly toward the center of the block. A few trees which could not be well sprayed on account of their situation with regard to irrigating ditches were more wormy than others. In the Rome Beauty section, in which there was a small crop the year previous, a total of 3,017 boxes of first-class fruit was packed, and it was estimated that one-fourth, or 109 boxes, of the culls and seconds were infested, or about 3 per cent of the whole crop. The Pewaukee apples were practically 100 per cent infested at the end of the season. The apples were counted on an unsprayed Domine tree September 4, and 81 per cent were found infested. From experiences in other orchards with this insect, the writer believes that, had it not been for spraying, the fruit in this orchard would have averaged from 80 to 90 per cent infested. (See Pls. XIII, XIV, XV.)

In Mr. Cash's orchard, which is separated from the Wilson orchard only by a road, it was found that the Jonathans were 25 per cent infested, only two sprayings having been made.

The orchard of Mr. Fremont Wood, which is a type of the best of the smaller commercial orchards, was kept under observation throughout the season. This orchard consists of about 1,000 trees, the larger per cent of which are Jonathan. These trees were set out about 1895. In 1901 the crop was small and was almost totally destroyed by the codling moth. In 1902 a hand-power spraying outfit was used (Pl. XII, fig. 3), which was supplemented by banding. The sprayings were made about the same time as in the Wilson orchard, except that the last spraying was after the rain, about the middle of August, and

it was probably more efficient on that account. After the first generation of the larvæ had entered the fruit, it was found that there were not over 3 to 5 wormy apples per tree. Harvesting was begun in October, and at that time it was found that in the Jonathan section, which consisted of about 900 trees, there were 4,700 boxes of first-class fruit packed. Of culls and windfalls there were about 900 boxes, of which, from numerous counts, it was estimated that about one-half, or 9 per cent of the entire crop, were infested.

Mr. McPherson's and Mr. Geckler's orchards are types of old commercial orchards in which the trees are large and the infestation bad. It was only with difficulty that remedial measures could be applied efficiently, as preventive measures had been neglected. In both instances, on account of the height of the trees and their closeness, the sprays could not be well applied. Mr. Geckler estimated his loss as high as 50 per cent, while Mr. McPherson lost as high as 30 per cent on the same varieties. In both of these orchards there is a constant supply of insects from other orchards, and their control requires radical application of preventive and remedial measures.

Mr. J. A. Fenton estimates that his crop was only about 15 per cent injured in 1902, he having used bands and spraying. Mr. I. L. Tiner, who has a small orchard in the city of Boise, estimated that he saves about 80 per cent of his fruit each year. Mr. Gus Goeldner, near Boise, estimates that he saves 90 to 95 per cent of his fruit each year. In many sections of the West estimates have been made by fruit growers in which they say they save from 85 to 98 per cent of their fruit. Sometimes these estimates are obtained from countings, but more often they can not be relied upon, the fallen fruit not having been taken into consideration.

The results of practical tests in these orchards show that with four or five thorough sprayings, preferably by a gasoline-power outfit, from about 85 to 95 per cent of the fruit can be saved from the codling moth. By a series of applications of these measures even this margin of loss may be reduced; but the saving of 90 per cent of the fruit under present conditions may be considered a solution of the problem.

RÉSUMÉ AND CONCLUSION.

The codling moth, which is now a cosmopolitan insect, was introduced into the Pacific northwest about 1880. On account of the warm climate two overlapping generations are produced, and if proper measures of control are neglected the insect, under normal conditions, will infest practically the entire apple crop of many localities.

The preventive measures are fully as important in controlling this insect as the remedial measures.

PLATE XIII.

CLEAN AND WORMY APPLES FROM TREE NO. 2, WILSON ORCHARD.

Showing 7 boxes of clean apples and 2 baskets or about 1 box of wormy apples.

CLEAN AND WORMY APPLES FROM TREE NO. 4, WILSON ORCHARD.

Showing 8 boxes of clean apples and one-half of a box of wormy apples from the tree (No. 4), and about 1¼ boxes of apples from the ground, of which about one-third were wormy.

CLEAN AND WORMY APPLES FROM TREE NO. 6, WILSON ORCHARD.

Showing 8 boxes of clean apples and 1 box of wormy apples from the tree, and 1 basket of clean apples and 1 basket of wormy apples from the ground.

PREPARING APPLES FOR MARKET, ORCHARD OF HON. FREMONT WOOD, BOISE, IDAHO.

Remedial measures which are of value have been found to be spraying with arsenites and banding. Spraying by the use of a gasoline-power outfit has proved to be the most effective, such spraying, using lime arsenite with soda, having reduced the injury in a certain orchard which had previously been from 40 to 60 per cent to 10 per cent.

By the use of proper preventive measures, spraying and banding, for a number of years, the injury due to the codling moth can be reduced from nearly 100 per cent to 5 or 10 per cent in an orchard in any locality.

BIBLIOGRAPHY OF MOST OF THE MORE IMPORTANT CONTRIBUTIONS TO THE LITERATURE OF THE CODLING MOTH.

The following bibliography down to 1898 is practically a duplicate of that published in Professor Slingerland's Bulletin 142, Cornell Agricultural Experiment Station, pages 63–69:

1635. Goedaerdt. Metamorphosis Naturalis, Vol. I, p. 98, fig. 46.

Apparently the first published account of the insect. It seems to have escaped notice until 1864, when Werneburg referred to it in his "Beitrage zur Schmetterlingskunde." Lister added nothing of importance in his Latin edition of Goedaerdt published in 1685.

1728. Frisch. Beschreibung von Allerley Insecten in Teutschland, part 7, pp. 16–17, Pl. X, figs. 1–5.

Grotesque and yet quite accurate descriptions of moth and larvæ; believed it preferred to work in unhealthy or injured fruits. No definite data on life history.

1736. Reaumur. Mem. pour servir a L'Histoire des Insects, Vol. II, pp. 484, 496–499, pl. 38, figs. 11, 12, and pl. 40, figs. 1–10.

Good account of work of larva in fruit and in making its cocoon. Two broods indicated.

1746. Roesel. Insecten-Belustigung, Vol. I, part 6, No. 13, pp. 33–37, pl. 13, figs. 1–5.

In accuracy of detail and coloring the hand-painted figures equal, if not excel, any colored pictures of the insect published since. Good account of original observations upon its life history; thought the newly hatched larva sometimes entered the fruit beneath the eggshell, and that the worms sometimes left one apple and went to another fresh one. One brood indicated. All stages, except the egg, well described.

1747. Wilkes. The English Moths and Butterflies, Book I, class 1, p. 5, no. 9, pl. 65 (copies of Roesel's figures).

Probably the first English account; brief compilation from Roesel. Gave to the insect its name of "codling moth," from the codling tree, which is also figured.

1758. Linné. Systema Naturæ. Ed. X, p. 538, no. 270. *Tinea pomonella*, "Alis nebulosis postice macula rubra aurea."

Original description of the insect when it received its first scientific name.

1791. Brahm. Insektenkalender, Vol. II, p. 465.

Brief account with many earlier references. Common and sometimes destructive in orchards; and records its habits in fruit rooms.

1802. De Tigny. Historie Nat. des Insectes, Vol. IX, p. 256.

Largely a compilation from Reaumur and Roesel. Says eggs are laid on fruit before petals fall.

1805. Bechstein and Scharfenberg. Natur. der Schäd. Forstinsekten, Part III, pp. 753–755.

Mostly a compilation from Roesel and Brahm.

1818. Hübner. Verz. Bekannt. Schmett, p. 375.

1819. TUFTS. Massachusetts Agricultural Repository and Journal, Vol. V, 364–367.

Apparently the first account of the insect in American literature. Previous American writers had credited the plum curculio with the cause of "wormy apples." Records some original breeding experiments by which he was led to conclude that the cause of most of the wormy apples in Massachusetts was a moth, and not a beetle or curculio.

1825. THATCHER. American Orchardist, second edition, p. 116.

Records finding the worms on the trunks of trees, and therefore advises scraping off the rough bark and washing trunks with Forsyth's composition. Apparently the first notice of the insect in horticultural books, and the first one to make any recommendations for controlling the insect.

1826. KIRBY and SPENCE. Introduction to Entomology, III, p. 123.

1829. TREITSCHKE. Die Schmetterlinge von Europa, Vol. VIII, pp. 161–163.

Many references to earlier literature. Descriptions. Brief compiled account of life history.

1831. CURTIS. Brit. Entom., VIII, pl. 352.

1833. "RUSTICUS." Entomological Magazine, Vol. I, pp. 144–146.

A very good detailed account of the life habits of the insect. Eggs laid in the calyx cup. One brood. Apparently the first important article in the English literature.

1833. BOUCHÉ. Garten-Insekten, pp. 113–114.

Brief compiled descriptions and account of habits. All that can be done to control it is to collect and feed out all wormy fruit as fast as it falls.

1834. STEPHENS. Ill. Brit. Ent. Haust., IV, p. 119.

1837. SCHMIDBERGER. In Kollar's Naturg. der schäd. Insecten. (For English translation see Loudon and Westwood's edition of Kollar, pp. 229–232, date 1840).

Good general account. Two broods indicated. (He published an earlier and more complete account in his Natur. der Obst. schäd. Insecten, to which we have not had access.)

1838. WESTWOOD. Gardiner's Magazine, Vol. XIV, pp. 234–239.

Mostly a good compilation from the accounts by Reaumur and "Rusticus." One brood indicated.

1840. BURRELLE. New England Farmer, Vol. XVIII, no. 48, June 3, p. 398. "On the Curculio."

Records breeding the moth. One brood only. Apparently the first one to suggest the famous "banding" method.

1840. RATZEBURG. Die Forst-Insecten, Vol. II, pp. 234–236, pl. 14. fig. 7.

Very good general account. Believes there is but one brood in North Germany, and doubts Schmidberger's account of two broods in South Germany.

1841. HARRIS. Insects of Massachusetts, pp. 351–355. (In the editions of 1852 and 1862 no change occurs.)

Very good general account. Only one brood indicated.

1843. GAYLORD. Trans. N. Y. State Agr. Soc., p. 158.

Brief account with Westwood's figure. Recommends allowing swine to run in orchard. Insect then common in New England, but very rare in the Middle States.

1844. LÖW. Schädliche Insecten, pp. 239–241.

Largely a compilation from Roesel, with good discussion of remedies.

1845. DOWNING. Fruits and Fruit-trees, p. 66.

Brief account.

1846. MORRIS, Miss. ("Old Lady.") American Agriculturist, Vol. V, February, pp. 65–66.

Good account, with original observations, and illustrated by what is probably the first original figure of the insect to appear in American literature.

1849. COLE. American Fruit Book, p. 89.

Brief account. Reports it numerous in New England and along the seaboard, and becoming more common in the Middle States.

1850. SIMPSON. The Horticulturist, Vol. IV, p. 567.
Brief account of breeding experiments. Two or three broods indicated. Discovered that a cloth in the crotch enticed many worms, and after experiments with wax recommends that trees be sprayed with whitewash to fill blossom end of fruits and thus prevent egg laying at this point.

1855. NÖRDLINGER. Kleinen Feinde der Landwirthschaft, pp. 339–346.
One of the best and most complete accounts which have appeared in the German literature. Very good discussion of remedies. Believes it is single brooded in Germany.

1859. JAEGER. The Life of North American Insects, pp. 179–181.
Brief, quaint account.

1861. GOUREAU. Les insectes nuis. aux Arbres fruitiers, pp. 118–121.
Very good general account. One brood in France.

1865. TRIMBLE. Treatise on the Insect Enemies of Fruit and Fruit Trees, pp. 103–139. Three full-page colored plates.
One of the best accounts in the American literature. Detailed notes on birds as enemies of the insect; "hay bands" devised and experiments recorded. Bred two broods at Newark, N. J.

1867. BOISDUVAL. Essai sur L'Entomologie Horticole, pp. 560–563.
Fairly good general account. One brood.

1868. WALSH and RILEY. American Entomologist, Vol. I, pp. 3–6.
Evidence in favor of allowing hogs to run in orchards.

1868. WALSH. Report on Insects of Illinois, pp. 27–29.
Arguments for two broods in Illinois.

1869. RILEY. First Missouri Rept. on Insects, pp. 62–67.
Good general account. Two broods.

1869. WALSH and RILEY. American Entomologist, Vol. I, pp. 112–114.
Very good general account, illustrated by Riley's well-known figures. Two broods.

1870. RILEY. American Entomologist, Vol. II, pp. 321, 322.
Records experimental proof of two broods in latitude of St. Louis, and discusses hay-bands vs. rags for trapping the worms.

1871. TASCHENBERG. Ent. für Gärtner und Gartenfreunde, pp. 310–313.
Good general account. Admits but one generation in Germany. (The same account occurs in his Prak. Insektenkunde, III, pp. 228-231; date, 1880.)

1871. ZELLER. Stettiner Entomologische Zeitung, p. 55.

1872. RILEY. Fourth Missouri Report, pp. 22–30.
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1873. RILEY. Fifth Missouri Report, pp. 46–52.
Records careful experiments with different traps on trunk, and the discovery of two parasites.

1873. LEBARON. Third Report on Insects of Illinois, pp. 167–185.
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1875. SAUNDERS. Report Ontario Entomological Society for 1874, pp. 43–50.
Good general account, largely compiled from LeBaron and Riley's writings. Two broods in Canada.

1875. COOK, A. J. Report Michigan Pomological Society for 1874, pp. 152–160.
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1878. THOMAS. Seventh Report State Entomologist of Illinois, p. 260.
Two generations indicated.

1879. WOODWARD. Rural New-Yorker, Feb. 8 (Proc. West. N. Y. Hort. Soc. for 1879, p. 20).
First published account of successful use of poisons (Paris green) against the codling moth.

1880. COOK. American Entomologist, Vol. III, p. 263. Also published in 1881 in Proc. Am. As. Ad. Sci. for 1880, p. 669; and in Rept. Mich. Hort. Soc. for 1880, p. 136.

Records the successful use of London purple to destroy the insect; first test of poisons made by entomologists.

1881. SCHMIDT-GÖBEL. Die schäd. und nützlichen Insecten, pp. 121–122.

Brief general account.

1881. COOKE. Insects injurious to California Fruit and Fruit Trees, pp. 13–19.

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1883. CHAPIN. Report Second Annual Convention of California Fruit Growers, pp. 17–25.

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1883. MANNING, JACOB W. Repelling and destroying codling moth. Trans. Mass. Hort. Soc., p. 10 ff.

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1884. ATKINS. Report Maine Board of Agriculture for 1883, pp. 356–363.

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1886. FORBES. Transactions Illinois Department of Agriculture for 1885, Appendix, pp. 26–45.

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1887. WICKSON. Bulletin 75, California Agricultural Experiment Station.

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1887. KLEES. Sixth Annual Fruit Growers' Convention (of California), p. 206.

1887. COOK, A. J. London purple against codling moth. Agricult. Sc., I, 9, Sept., 1887, p. 215.

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Results of scientific experiments with Paris green, London purple, and arsenic in 1886. Comparison of one, two, and three applications. Three broods indicated.

1887–88. CLAYPOLE, E. W. Spraying for the codling moth. 21st Report Hort. Soc. Ohio, pp. 212–214.

1888. HOWARD. Report U. S. Department of Agriculture for 1887, pp. 88–115.

The best and most exhaustive discussion of the insect at that time. From it have been compiled most subsequent discussions of habits and life history. Colored plate.

1888. COOK. Bul. 39, Michigan Experiment Station, pp. 1–4.

Results from one, two, and three sprayings, and general conclusions from eight years' experimenting with poisons.

1888. MCMILLAN. Bul. 2, Nebraska Experiment Station, pp. 68–77.

Very good general discussion of habits and especially of remedies.

1888. POPENOE and MARLATT. First Report Kansas Experiment Station, pp. 165–193.

Valuable record of careful experiments with poisons and bands, including tables giving dates of blossoming of many varieties of apples.

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Comparative test of Paris green and London purple, showing slight advantage for the former.

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1892. THOMPSON. Handbook to the Insect Pests of Farm and Orchard (Tasmania), Part I, pp. 34–54.
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1892. LODEMAN. Bul. 48, Cornell Experiment Station, pp. 268–274.
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1892. OLLIFF. Entomological Bul. 1, Dept. Agr., New South Wales.

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1892. KELLOGG. Common Injurious Insects of Kansas, pp. 78–80.
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1893. WASHBURN. Bul. 25, Oregon Experiment Station, pp. 1–8.
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